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Airplane pilot talking by wireless phone with a ground station

RADIO TELEPHONY (see page 280)

What the Weather Man Thinks of Ocean Flying*—I

Trans-Atlantic Flight from the Meteorologist's Point of View

By Willis Rey Gregg, Meteorologist of the U. S. Weather Bureau

Detailed as Consulting Meteorologist to Proceed to Newfoundland in Order to Advise Aviators as to Weather Conditions

The marvellous development of aviation finds no better illustration than the fact that, within 15 years of the time when flying in heavier-than-air machines was proved to be practicable, trans-Atlantic flight has become one of the leading topics in the daily press and is receiving the earnest attention of many of our most ambitious aviators. Heretofore discussions of the subject have for the most part dealt with the mechanical problems involved, including engine performance, endurance, fuel capacity, etc. Comparatively little has been written relative to the meteorological aspects of the project. It is true that improvements in aircraft may eventually result in making them less dependent upon weather conditions than at present, but it is not likely that the time will ever come when a knowledge of atmospheric conditions and changes cannot be used to advantage by the aviator.

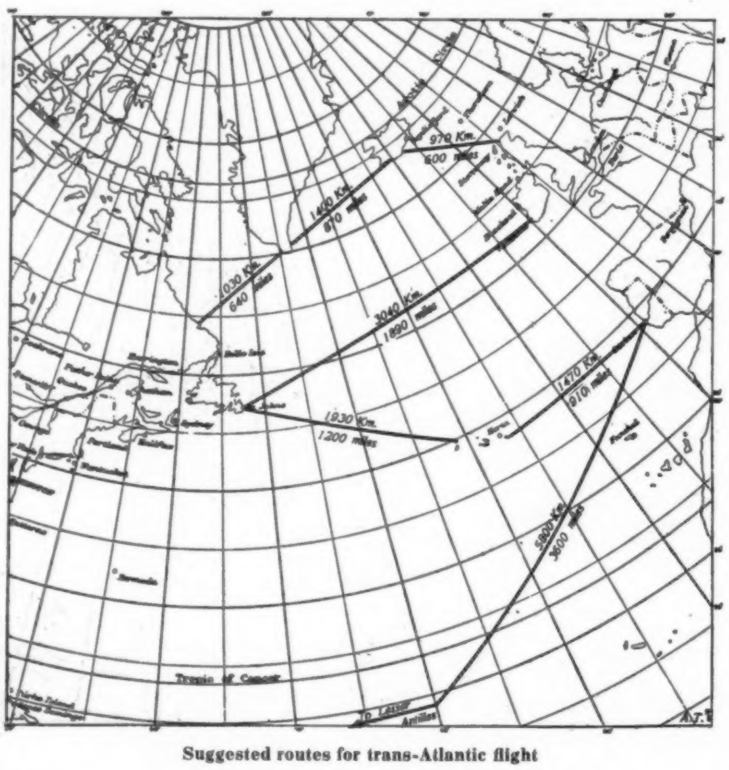
Before taking up this matter in detail a few words should be said as to possible routes. Those most frequently proposed for the trip from America to Europe and return are (*a*) Newfoundland to Ireland and (*b*) Newfoundland to the Azores, thence to Portugal. Another suggested route is from Labrador to Scotland, via Greenland and Iceland. The only advantage of this route over the others is the shorter distance between successive landing points. Among its disadvantages are: Lower temperatures than over the routes farther south; difficulty of providing suitable landing places in Greenland and Iceland and of finding them even if they could be established; greater probability of cloudiness and of opposing winds, since this route lies to the north of the region of greatest storm frequency; difficulty, if not impossibility, of securing meteorological data at the time of flight; and remoteness from steamship routes and, therefore, improbability of rescue in case of accident. Inasmuch as airplanes of sufficient power and capacity have been developed for flying a distance at least as great as that from Newfoundand to the Azores the extreme northern route will be given no further consideration.

For the return trip from Europe to America there have been proposed in addition to the two already mentioned, a route from Portugal to northern Brazil, Guiana, or Venezuela; and one from Portugal to the Lesser Antilles. In these instances, however, the flights contemplated were to be made by means of relatively slow-traveling airships or dirigible balloons. For the eastward journey they were to go direct from Newfoundland to Ireland, thus adding to the inherent speed of the airship the assistance furnished by the prevailing westerlies. In returning, however, the wind resistance offered would be so great as to make the journey hazardous and on a large percentage of days impossible. The southern routes would not only avoid these head winds, but would lie for the most part in the region of the northeast trades. In spite of their greater distances, therefore, these southern routes offered decided advantages for airships or dirigible balloons. In the case of high-speed airplanes, on the other hand, the assistance furnished by the trade winds would be offset in large part, if not altogether, by the greater distance to be traveled. On properly selected days the less favorable winds along the routes farther north would be more than compensated for by the shorter distances. Attention will therefore be given only to the routes between Newfoundland and Ireland and between Newfoundland and Portugal via the Azores.

AVERAGE SURFACE WEATHER CONDITIONS OVER THE NORTH ATLANTIC.

Temperatures are of interest chiefly in connection with their effect upon the aviators and upon engine performance. For St. John, N. F., the mean annual temperature is 5° Cent.; for Valentia, Ire., 10°; for the Azores, 18°; for Lisbon, 15°. Annual and diurnal ranges, as well as those due to abrupt changes in weather, are greatest in Newfoundland and least in the Azores. Minimum temperatures as low as —25° C. have been observed in St. Johns and as low as —5° C. at Valentia. Freezing temperatures have never been reported in the Azores or at Lisbon. Extreme maxima do not differ greatly at the four places, Lisbon showing the highest, 35° C., and Valentia the lowest, 27° C. Over the ocean the horizontal temperature gradient is fairly steep in winter from Newfoundland to longitude 40° W. along both routes, and practically zero from that longitude to Ireland and Portugal. During the summer there is a slight rise from Newfoundland to longitude 45° W. over the Azores route; along the remainder of this course and along the entire course from Newfoundland to Ireland there is practically no change.

Comparatively little has been done in a critical way in the study of humidity conditions over the oceans. Among the most interesting observations are those on the British steamship *Scotia* and on the U. S. Coast Guard Cutter *Seneca*. These observations were made in the late spring and early summer months and showed in practically all cases a relative humidity above 80 per cent. A large number of observations in December, as computed by the marine section of the Weather Bureau, gave an average value of 86 per cent. There seems to be little, if any, variation with the seasons, but there is a small variation with latitude, values at latitude 60° N. averaging about 90 per cent., as against 85 per cent. at latitudes 40° to 50° N.



Suggested routes for trans-Atlantic flight

The average cloudiness along the northern route is about 70 per cent. throughout the year. This statement is somewhat misleading, so far as aviation is concerned, inasmuch as fogs are included with clouds in arriving at this result and, as will be shown later, these fogs extend to low altitudes only. The aviator would often have a clear sky above him, whereas at the earth's surface 100 per cent. cloudiness would be recorded. It is probable that in summer the average cloudiness above the fog level is about 50 to 60 per cent. Between Newfoundland and the Azores it varies from 65 per cent. in winter to 55 per cent. in summer, and between the Azores and Portugal, from 55 to 45 per cent.

Very little is known as to the amount of precipitation over the North Atlantic Ocean. Data are available, however, for the adjoining coasts and these indicate an annual amount of about 140 cm. in Newfoundland; 100 on the west coast of Ireland and in the Azores; and about 70 in southern Portugal. According to Supan the average is about 200 cm. over the greater portion of the Newfoundland-Ireland route, and over part of the region between Newfoundland and the Azores; from the latter to Portugal the mean value is probably about 100 cm. Precipitation normally occurs on about 160 days in Newfoundland; 200 in Ireland; 170 at the Azores; and 100 in Portugal. Over the ocean it probably occurs on about 200 to 250 days along the northern route and on about 150 to 200 days along the southern route. In all regions precipitation is greatest in winter and least in summer.

One of the most serious obstacles to trans-Atlantic flight appears to be the large percentage of days on which fog occurs, particularly near the American coast. This amounts in the regions southeast and east of Newfoundland to about 60 per cent. in summer and about 20 to 35 per cent. in winter, the frequency in the latter season being greatest to the southeast. Near the Irish coast it varies from about 10 per cent. in summer to 5 per cent in winter. Fogs rarely occur near the Azores or between them and Portugal. A surprising feature of this part of the Atlantic is a calm-weather fog of small vertical extent in which the sea is slightly warmer than the air. In discussing this phenomenon Taylor concludes "either that when a fog blows over warmer water there is no appreciable tendency to dissipate it or that, under certain circumstances, warm water under cold air tends to produce a fog in some other way than that with which we are familiar and that this effect balances the tendency of warm water to dissipate a fog produced by cooling." Probably such fogs are of a temporary nature, having already been formed under the usual conditions, but later blown over water with a higher temperature than their own. They occur only during calm weather and quickly disperse as soon as a breeze sets in.

Pressure distribution over the North Atlantic may be briefly described as consisting essentially of a belt of high pressure, known as the "Horse Latitudes" at about latitudes 30° to 35° N., with a semi-permanent high near the Azores; and a belt of low pressure at about latitude 60° N. with lowest values in the vicinity of Iceland. Because of the relative warmth of the ocean and the adjacent continental areas during the different seasons, the Azores high is best developed in summer and the Iceland low in winter. The seasonal difference is greatest in the case of the Iceland low, the final result being that the northward pressure gradient is strong in winter, but relatively weak in summer. The isobars, in general, run more or less parallel to the lines of latitude from Newfoundland to about longitude 20° W. at all seasons. Farther east along the Ireland route they continue eastward in summer, but turn to east-northeast and northeast in winter, under the influence of the Iceland low. From the Azores to Portugal they turn southward in summer around the Azores high, but are nearly west to east during the winter.

As a result of the pressure distribution which is thus briefly outlined, winds in summer are from a west-southwesterly direction, with a mean velocity of 8 meters per second, at all points along the northern route; in winter they are westerly, with a slight component from the north, mean velocity about 10 m. p. s., from Newfoundland to longitude 45° W. Farther east they have a strong south component, becoming southwesterly near the British Isles. The mean velocity along this section of the course is 10 to 15 m. p. s., being highest between longitudes 45° and 20° W. Over the southern course winds in summer are southwesterly, 8 m. p. s., to longitude 40° W.; variable and light thence to the Azores; and northerly, 8 m. p. s., between the Azores and Portugal. In winter they are west-northwesterly, 10 m. p. s., to longitude 40° W.; westerly, 10 to 12 m. p. s., thence to the Azores; and west-southwesterly, 10 m. p. s., between the Azores and Portugal. The percentage of winds from a westerly direction, i. e., between north-northwest and south-southwest, varies along the northern route from about 85

*Appearing in the Monthly Weather Review.

in winter to 70 in summer; near the Azores, from 75 to 65; and from the Azores to Portugal, 40 to 30. In the last-named region winds from all directions are about equally frequent in winter, but in summer northerly winds predominate.

Practically all of the cyclonic disturbances that move across the United States, no matter what their place of origin, enter the North Atlantic Ocean slightly to the south of Newfoundland, moving thence east-northeastward toward the Iceland low, and thus crossing the northern route roughly between longitudes 30° and 40° W. These storms vary considerably in size, intensity, and rate of travel. In general, they are larger and travel more slowly over the ocean than over the continents. They are, moreover, more frequent, more intense and faster moving in winter than in summer. In their movements across the Atlantic, the more intense cyclones are often accompanied by gales having a velocity of more than 20 m. p. s., the directions of these gales depending upon the part of the storm in which the observations are made. Thus considering a typical case, viz., a well-developed low leaving New England and passing south and eventually east of Newfoundland, we should expect to have at the latter place gales successively from the east, northeast, north, northwest, and west. Along the Ireland route the percentage of days on which such gales occur varies in general from about 25 in winter to 5 in summer. In winter they are often accompanied by violent snow squalls. From Newfoundland to the Azores the percentage frequency of gales is about 20 in winter and 3 in summer; from the Azores to Portugal, about 7 and 1, respectively.

AVERAGE FREE-AIR CONDITIONS OVER THE NORTH ATLANTIC.

On this subject there is but little information available, so far as actual observations are concerned. The following discussion is, therefore, based for the most part on numerous free-air observations that have been made over the eastern portions of the United States and Canada and in different parts of Europe, and an effort is made to apply these results to the air over the ocean, bearing in mind the relative effects of land and water surfaces on the distribution of the meteorological elements above them.

Individual observations over land surfaces show, in the lower layers of the atmosphere, large variations in temperature gradients, from a strongly inverted condition to nearly (sometimes slightly exceeding) the adiabatic rate. The diurnal phase, so characteristic of surface temperatures, disappears at a low altitude, and at higher levels in clear weather there is usually a reversal, due probably to the greater absorption of terrestrial radiation in those levels at night than during the day. The annual variation is also less in the free air than at the surface, with the result that in winter there is on the average little change in temperature from the surface to a height of about 1 kilometer above it, whereas in summer a decrease of about 6° C. occurs. In general, it may be said that the lower the surface temperatures, as compared with the seasonal normal, the smaller is the rate of decrease with altitude. In other words, during cold waves with clear skies and especially during the early morning hours, inversions almost invariably occur. During cloudy weather, i. e., low clouds, temperatures generally decrease from the surface to the cloud layer and increase slightly for a short distance above it.

In the application of the foregoing statements to the free air above the ocean it is important to recognize certain fundamental differences between land and water surfaces in their absorption and radiation of temperature. Water surfaces reflect about 40 per cent. of the insolation that reaches them and absorb the remaining 60 per cent. Much of the heat thus absorbed is, however, used in evaporating the water and some of the remainder is distributed both vertically and horizontally by the constant movement of the water and by the penetration of the light rays to lower levels, the result being that the surface and therefore the air in contact with it maintains a relatively constant temperature. Land areas, on the other hand, reflect and transmit very little insolation and there is but little evaporation. The specific heat of land is low and moreover there is no movement, as in the case of water, whereby the heat received can be convectionally distributed either horizontally or vertically. Hence, land areas become strongly heated during insolation and similarly cooled in its absence.

The diurnal variation of temperature at the surface in any one locality at sea is seldom greater than 1° C. In general it is probable that the change is not much larger in the free air above the ocean, except that, in the case of coastal waters, winds blowing offshore would bring their characteristic diurnal variations of temperature with them. As has already been stated there is in winter considerable change in surface temperatures from Newfoundland eastward. This is due partly to the effect of the cold winds blowing off the American continent and partly to the difference in temperature of the Labrador Current and the Gulf Stream. In the free air this difference largely disappears. Observations on the *Seneca* invariably showed a sharp inversion above the cold Labrador Current and the coastal waters, whereas a temperature decrease of 0.5° to 0.6° C. per 100 meters was found above the Gulf Stream. Summarizing, then, we should expect to find at 1 kilometer above the sea approximately the conditions as set forth in Table 2. The summer months include June, July, August and September and the winter months, December, January, February, and March. Transitions from one group to the other during spring and autumn are gradual.

TABLE 2.—*Probable temperature conditions, °C., at 1 kilometer above sea in different portions of the North Atlantic.*

	Near Newfoundland.		Near Ireland.		Between Azores and Portugal.	
	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.
Mean......	10	0	10	5	15	10
Highest....	25	10	20	10	25	20
Lowest.....	5	—10	5	—5	10	5

It must be distinctly understood that these figures are merely estimates; they are the nearest to actual conditions that we can get at the present time. They indicate that at an altitude of 1 kilometer temperature changes along both routes would be less than at the surface, that rarely would temperatures be much below freezing along any part of either route, and that in summer a trip would be attended by mild and comfortable temperatures throughout. The fogs off the coast of Newfoundland should cause no concern in this respect, for, as will shortly be shown, they are low-lying, and above them temperatures are higher than at the surface.

Over land areas relative humidity generally decreases with altitude during clear weather or when only high clouds of the cirrus type are present. As a rule, it falls to about 50 per cent. at an altitude of 1 kilometer, but occasionally as low as 20 per cent. When there are low clouds, the humidity remains high to the upper limits of the cloud layer and decreases rapidly above it. When all conditions of weather are considered, the average decrease with height is not large, amounting to only about 10 per cent. from the surface to 1 kilometer above it. It is greatest in winter and least in summer. At altitudes greater than 1 kilometer the relative humidity remains practically constant. Above the ocean, due to the higher humidities at the surface, this decrease is probably larger, amounting on the average to 20 or 30 per cent. The *Scotia* observations showed in some cases exceedingly low values at altitudes of less than a kilometer, even with dense fog at the surface. In general, it is probable that an aviator being at an altitude of about 1 kilometer would experience along the northern route humidities of 50 to 60 per cent. in clear weather or when only high clouds are present and about 80 to 100 per cent. in weather with low-lying clouds. Along the southern route somewhat lower humidities than 50 per cent. would prevail during clear weather, but with overcast skies they would be about the same as along the northern route.

There is every reason to believe that in the great majority of cases fogs extend to a low altitude only, above the sea. This is clearly shown in the kite records obtained on the *Scotia* and on the *Seneca*. The top of the fog is very definite, and above it the relative humidity decreases rapidly. The temperature usually increases from the surface to the top of the fog and decreases above it. Out of nine kite records in fog obtained on the *Scotia* only one showed fog extending to a height greater than 300 meters, the average being about 150 meters. Ten kite flights in fog were made from the deck of the *Seneca*, and the temperature gradients indicate that in only one did the fog extend to a height greater than 250 meters. In fact, there is nearly always a higher temperature at the top of the mast than on the ship's deck and, if this temperature increase continues to greater heights (and kite records show this to be true), a point must soon be reached at which fog is impossible. Additional testimony from local observers, in support of these conclusions, is contained in a recently printed report of the British civil aerial transport committee.

Observations with kites and balloons in this country and in Europe have brought out the following facts with respect to average free-air wind conditions: Velocities are slightly greater at all altitudes in America than in Europe, but aside from this difference the same general tendencies are shown in both countries, viz., a rapid increase, amounting to very nearly 100 per cent., from the surface to about 500 meters above it; practically constant velocity in summer and a small increase in winter from the 500 to the 1,000 meter levels above the surface; and a steady increase in both seasons, but greater in winter than in summer, from the 1,000-meter level above the surface to greater altitudes. The mean seasonal difference is about 1 m. p. s. at the surface and 2 to 4 m. p. s. at an altitude of 1 kilometer. Moreover, all observations show that the increase in wind velocity from the surface to 500 meters above it is practically the same for all directions of wind, but that at higher levels winds from an easterly direction rapidly diminish in strength, whereas those from a westerly direction gradually increase. The easterly winds usually die out altogether before an altitude of 2,000 meters is reached and at higher levels westerly winds prevail. The shifting from one type to the other is nearly always clockwise with surface winds from east to south and as a rule counterclockwise with surface northeast to north winds. The amount of the turning is directly related to the angle of deviation of the surface wind direction from that of the prevailing westerlies.

Winds, as is well known, tend to flow at right angles to the direction in which the pressure gradient acts, i. e., parallel to the isobars. Owing, however, to friction and eddies, the direction of motion of the surface wind is nearly always inclined to the isobars. The amount of this inclination is greatest in anticyclonic and least in cyclonic systems, the average value on land surfaces being about 30°. Inasmuch as these disturbing influences largely disappear in the free air, we should expect the winds invariably to veer with altitude. This veering with altitude is at times visible in the way in which the smoke from steamers spreads. That there are exceptions is due to the unequal vertical distribution of temperature that often obtains in adjacent localities, thus producing in the free air isobaric systems decidedly different from those at the surface. Nevertheless, in general it is found that the winds at an altitude of 1 kilometer follow rather closely the direction of the surface isobars. This means that on the average they veer about 30° from those near the ground. The case is somewhat different over the ocean. Here there is less friction, less convection, and there are no topographic interferences at all comparable with those on land. Hence we should expect to find the winds even at the surface blowing more nearly parallel to the isobars, and an inspection of marine synoptic weather maps indicates that this is true, the average inclination being about 10°. This means that the veering of winds with altitude is about 20° less over ocean than over land surfaces. In a similar manner velocities are affected, with the result that they are higher on the sea than on land, that is, they more nearly approach true gradient velocities. It has already been stated that observations show above land an increase of about 100 per cent. in velocity within the first 500 to 1,000 meters. Now, surface winds at sea are nearly twice as strong as those on land. Hence the increase with altitude over the sea is much less than over the land. In other words, a trans-Atlantic aviator would not need to fly as high as would a transcontinental aviator in order to derive the greatest possible assistance from the winds; and, conversely, in the case of opposing winds there would be less advantage in flying at a low altitude over the ocean than over the land. Whatever the wind direction, whether favorable or unfavorable, flying at low levels above the sea would be less dangerous than at similar levels above the land, because the air there is less turbulent or "bumpy," as it is sometimes called.

(TO BE CONTINUED.)

New Process for Making Parabolic Mirrors

ONE of the great factories entirely devoted to war work has succeeded in making satisfactory parabolic mirrors by chemical processes thereby saving time and reducing weight. A highly polished glass mirror formed the pattern. Silver was deposited chemically, the layer increased electrolytically, 1/16 in. copper added by a special plating method, and this backed by a suitable thickness of a cementing material. The difference in expansion between glass and metal served to separate the metallic portion from the glass mold, after which the silver surface was protected with a waterproof, chemically-prepared lacquer capable of withstanding the necessary temperature. Such mirrors gave satisfactory results, and they can be made very quickly as compared with grinding and polishing glass. The mountings required were also much lighter.—*Jour. Soc. Chem. Ind.*

The Coconut Palm*

Its Culture and Uses, with Special Reference to the Industry in the Philippine Islands

By P. J. Wester, Agricultural Adviser, Department of Mindinao and Sulu

The coconut, *Cocos nucifera L.*, is a tall unarmed, monœcious palm, attaining a height of about 25 meters, with a stout, scarred trunk and swelled base, to which are attached 4,000 to 7,000 or more coarse roots, of a remarkably uniform diameter, about 9 centimeters thick, and from 5 to 7 meters long, rarely exceeding 8 meters except in very sandy, poor soil, spreading, seldom descending beyond a depth of 1 meter. The leaves are 4 to sometimes exceeding 6 meters in length, pinnate, and are crowned at the apex of the trunk; the petiole is stout, 1 meter or more long; the leaflets are numerous, up to 1 meter in length, linear-lanceolate, acuminate and leathery. The inflorescence is an axillary panicle up to 1 meter long; the flowers are numerous, small, fragrant and honey-bearing. The fruit is variable in size and shape, 15 to 25 centimeters long, obovoid to subglobose or somewhat flattened, frequently obscurely 3-angled, consisting of a fibrous husk in which is embedded a large seed or "nut," the meat of which lines the inside of the bony endocarp or "shell."

The coconut has been believed by some authorities to be of Asiatic origin, but that its original home was America is now generally conceded. Of prehistoric introduction into Polynesia and tropical Asia, the coconut did not become generally distributed throughout the American tropics until after the discovery of America. The coconut is now well dispersed throughout all parts of the tropics.

Because of the comparatively recent agricultural importance achieved by the coconut, very little systematic study has been made of the different coconut varieties, and no attempt seems to have been made to bring together the different forms from the various countries of the tropics except by the French Colonial Government in Madagascar. From the meager and somewhat contradictory statements by different authors, there seems to be a wide field here for original and interesting study of no little practical value.

While it is conceded that there is still much to learn about coconut varieties, the existing literature seems to indicate there are altogether probably not more than 35 distinct coconut varieties, a remarkably small number considering the antiquity of the cultivation and the wide distribution of the coconut. In a plant that must be propagated from seed and is so long-lived, this constancy of characteristics is a distinct advantage; for were the coconut to be even approximately as variable as many of the temperate fruits of the monoembryonic mangos of India, the planting of coconuts would be a vastly more hazardous undertaking than it is now. Climate and soil naturally affect a variety more or less in changing from one set of conditions to another, but in the main a variety may be depended upon to reproduce itself true to type.

As in other agricultural enterprises, there are several elements that combine to determine success or failure in coconut growing. These are climate, soil, susceptibility to diseases or other agricultural pests, cost of the land, transportation facilities and accessibility to markets, and availability of labor; last but not least comes the manager or superintendent.

While for ornamental purposes the coconut may be grown somewhat beyond the torrid zone, in the broad sense the usefulness of this palm as a plantation crop is limited to the tropics. Near the equator the altitudinal range within which the coconut may be profitably cultivated as a plantation crop extends from sea level to an altitude of perhaps 500 meters; beyond this elevation, although the tree may occasionally be grown for home consumption even above 800 meters, the palm cannot be recommended for planting on a large scale. These elevations naturally decrease according to the distance from the equator. Other conditions being equal, the coconut thrives best and is most productive where the precipitation is equal throughout all months of the year, with no prolonged dry periods. If the rainfall is of equal distribution throughout all the months of the year, the coconut may be grown with an annual rainfall of 1,500 millimeters or even less if the ground water ascends within the reach of the root system. On the other hand it succeeds well where the precipitation exceeds 3,000 millimeters.

For the best results the dry season should perhaps not extend beyond three months, depending to a considerable extent upon the atmospherical humidity and the proximity of ground water. Extreme humidity is said to cause premature decay of the nut, but this is a vary rare occurrence and need scarcely be considered in the selection of a site. It is well to remember that the assimilation of plant food and consequently the development and ripening of the nuts is closely related to the amount of sunlight the palms receive. Therefore, other things being equal, that locality with the greatest number of sunny days in the year is the one most favorable for the maximum production of nuts. Whether or not atmospheric stillness or prevalent winds are the most beneficial for the coconut is a mooted question, and may perhaps be considered as of academic interest rather than of very great practical value. At any rate it is not believed to be of sufficient importance to turn the scale in deciding upon a site for a plantation. Storms and typhoons are of course destructive to the season's crop, and where sufficiently severe may do permanent damage to the trees. For the benefit of those who still cling to the belief that the coconut is dependent upon the salt air and breezes of the shore for its best development, it may be briefly stated that there is no sound foundation for such a contention, nor, for that matter, for the belief that salt is beneficial to the tree.

*From the Philippine Agricultural Review.

A one-year-old coconut under clean culture

An eight-year-old tree at Zamboanga

Coconut tree with bamboo bridges for gathering palm wine

An alluvial, loamy, volcanic or sandy, friable, fertile soil at least 60 centimeters deep, is well adapted to the coconut. Gravel and laterite in moderate amounts are rather beneficial than not. Heavy, compact, water-retaining soils are unsuitable to this palm. It is impatient of stagnant water, but will grow even where the ground water comes close to the surface, provided that there is a constant movement of the water in the soil. Occasional inundations, provided that they are not of long duration, do not injure it.

In relation to immunity from coconut pests, the entrance thereof can naturally be better guarded against, or they may be more easily controlled, where the plantation is located on a small island under the absolute jurisdiction, so far as coconuts are concerned, of the owner, than it can on a large island. Therefore, everything else being equal, a small island, somewhat larger than the proposed plantation, or a peninsula, would be the most preferable site for a coconut estate. In the selection of such a site depth of water and the feasibility of the construction of docking facilities should also be considered, especially where the development of a very large estate is contemplated.

So far as the writer is aware, no studies have been made of the heredity of the coconut, and it is not known to what degree the various characters of this palm are transmissible. In the meantime it is a safe rule, and in fact it should be the rule, to select for seed nuts those from vigorous, productive trees bearing large nuts that are well developed. Those who wish to carry selection still further should compare the amount of meat and the oil content of the nuts from the individual trees. In fact every coconut planter should keep a performance record of his coconut trees from year to year in order to enable him to extend his plantation with seedlings from his most productive trees. There is no doubt but that such a record would bring to light some very surprising and perhaps unexpected facts.

The most productive coconut trees having been ascertained, the seed nuts from these should be lowered to the ground by hand. It should be remembered that these nuts are worth intrinsically much more than the nuts that are made into copra, and that a cracked nut decays and does not germinate; the extra expense in picking these nuts carefully is therefore well justified.

After gathering, the seed nuts should be stacked in a dry, airy place to "cure" for about a month before planting. The nuts are ready to plant in the seed bed when most of the milk has dried up and the meat is hard.

The seed bed should be plowed repeatedly or spaded, and all roots and trash removed until the land is well worked up to a depth of 30 centimeters.

In planting, the nuts should be spaced so that they are about 7.5 centimeters apart and should be laid on the side, and about one-half to two-thirds of the nut buried in the ground. Then a thin mulch of chopped rice straw, grass or weeds should be placed over the seed beds in order to maintain an even moisture in the soil and prevent the drying out of the nuts. If the mulching has been properly attended to, with one thorough watering of the seed beds after the seed are planted, there should be little or no need for additional irrigation. The erection of a temporary shed of palm leaves or cogon for protection from the sun is advan-

tageous in many cases but not always essential.

The plants are ready for transplanting to the field when they are 50 to 75 centimeters high and the roots extend 10 to 20 centimeters beyond the husk. In fact the transplanting to the field should not be delayed beyond this stage.

All the best authorities on coconuts are agreed that coconuts should not be spaced closer than 8 to 10 meters, depending upon the fertility of the land, and some recommend a distance of 12 meters apart. Ten meters apart is certainly not too great where the soil is rich.

Whatever the distance, the plantation should be laid out in straight rows and the trees set out equidistant in order to facilitate the work in the plantation, to enable the roots to fully utilize the space in the soil, and in order that the tops may equally share the full benefit of the sunlight, for, other conditions being equal, the tree that is most exposed to the light bears the heaviest crops.

As a rule plantations are usually set out according to the square or rectangular system. According to this system the trees are planted so that the rows intersect each other at right angles. If this system is used, the staking operation is most easily performed in the following manner:

The hexagonal or sextuple system of planting has an advantage over the square system in that by its use approximately 15 per cent. more trees can be planted on a given area without additional crowding of the trees than by the use of the square system. The basis of the hexagonal system is the circle instead of the square, six trees being set out equidistant from a seventh placed in the center. The hexagonal is the only system that equally divides the space between the trees. In planting according to this system the staking is facilitated by marking the wire for the stakes alternately with two colors.

In regions subject to heavy winds it may be beneficial to plant wind belts here and there in the plantation. These should consist of strong-growing, vigorous, deep-rooted trees, fruit trees, preferably, well adapted to the region. Among such trees may be mentioned the various species of *Mangifera*, the tamarind, or the mabolo. The bamboo also makes an excellent wind break, but it impoverishes the soil over too great an area around the plants to be entirely suitable for this purpose.

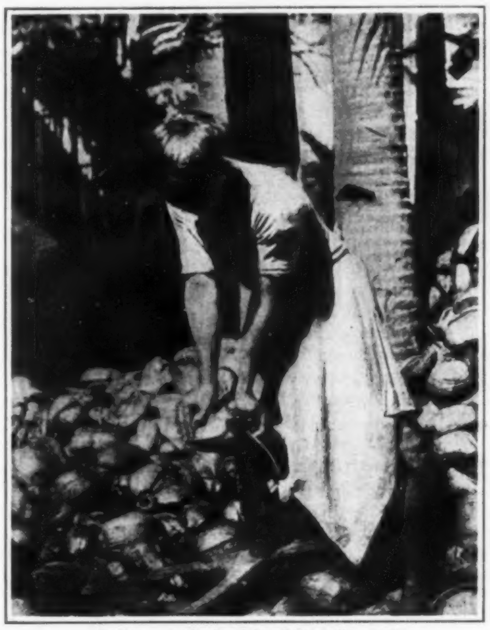
It is good practice to dig the holes at least one or two months in advance of the transplanting. The size of the holes depends upon the quality and preparation of the land, the largest holes being necessary on heavy soils or where laterite is abundant. The holes should never be dug less than 50 centimeters in diameter and 50 centimeters deep, and where the ground is not in the best condition a hole 0.75 to 1 meter in diameter is better.

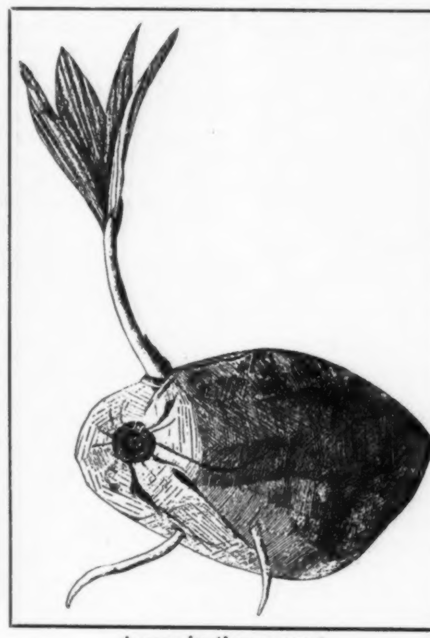
The best practice is unquestionably to transplant the coconut palms from the nursery to the field while the young plants are still firmly attached to the nut and derive the major part of their sustenance therefrom. If transplanted at this stage the nut will be able to assist the plant to recuperate from the shock of transplanting, which at a later stage it cannot do; the cost of transplantation is decreased through the handling of smaller plants, and the danger of loss from the transplanting is smaller when the plants are young than after they have put out several leaves. The transplantation to the field of plants over two years of age is impracticable owing to the expense entailed by the operation.

When the plants are set out in the field as recommended, there is no need to prune the leaves, but if set out after the root system is established in the nursery, it is good practice to remove about one-third of the leaf area of the plants before digging begins in order to reduce evaporation until the plants are well established in their new quarters. The plants should be dug from the nursery with a sharp spade, the young plants should be carefully handled, and care should be taken to avoid bruising and drying of the roots.

The transplanting should be performed sufficiently early during the rainy season to permit the young palms to become well established without the extra expense of watering by hand, and it is well to time the actual work of setting the plants so that it is accompanied by a good rain.

The holes should be filled with surface soil carefully worked in between the roots and well packed around them and the nut, setting the nut so deep that the upper surface of the mother nut is about even with the ground in the field. If the growing of auxiliary crops is not contemplated, the lands should be planted to leguminous cover crop immediately after setting out the coconut plants in the field.


Native method of husking the nuts


A germinating coconut

Plowing and cultivation will assist in liberating all plant foods, and nitrogen can be cheaply added to the soil by means of green manures. So far as is compatible with sound business management depending upon local conditions, such as cost of labor, all the smaller parts of the leaves of the trees should be left to decay, and the larger parts burned and the ashes scattered among the trees. This is likewise true of the husks also and their ashes.

If we consider that the careful planter returns the leaves and the husks and shells or their ashes, according to analyses made by Walker in Mindanao, an annual crop of 7,000 nuts would remove from each hectare in the copra and milk 43.57 kilos of nitrogen, 26.51 kilos of potash, and 13.37 kilos of phosphoric acid. If the husks and shells were not returned to the soil these figures would be 59.42, 60.55, and 16.73 kilos, respectively. The removal of plant food by the leaves need not be considered, taking for granted that these are decayed or burned in the plantation as a matter of course. This is a remarkably light drain upon the fertility of the land considering the value of the crop, particularly contrasted with other crops, such as corn and tobacco. Roughly speaking it will thus be seen that the loss of nitrogen is about three times that of the loss of phosphoric acid, while the loss of potash is twice as heavy where the meat and milk only are removed. In the case of the removal of the entire nut, the loss of nitrogen and potash is about equal, and about five times the loss of phosphoric acid.


Coconut rafts on the Pagsanjan River, Laguna

While he will do well to keep these figures in mind, the intelligent planter who has selected his land with due care should not need to worry over fertilizer bills for many years. Depletion of soil fertility is soon indicated both by the growth and the appearance of the trees and by the yield; this may then be corrected by the application of artificial manures. Nevertheless, where it is obtainable at a reasonable cost the application of cattle manure, fish refuse, and seaweed will be found beneficial. Near saw mills, wood ashes may be taken advantage of and should, of course, preferably be unleached.

The growth of the young palms is stimulated by an abundance of nitrogen, which has been provided for if green manure crops are grown. Later, when the trees become of bearing age, phosphatic manures and those rich in potash would be the most likely to encourage fruit production.

In large plantation practice the coconut is ultimately cultivated for the coconut oil, which is made from the copra obtained from the coconut. The oil content of the copra depends upon the stage or development of the coconut at the time of harvesting. For the production of a high-grade copra it is essential that the nuts remain on the tree until they are fully ripe. Then, again, it should be kept in mind that copra made from immature nuts has a tendency to absorb water from the atmosphere even after it is thoroughly dried, which induces fermentation and molding, with a corresponding loss of oil.

If not picked prematurely the coconuts remain on the trees until thoroughly ripe when they drop from the trees of their own accord, and they are then in such condition that they rarely crack, while in unripe nuts so dropped in the course of picking cracking is a common occurrence. Most authorities are agreed that the best method of harvesting coconuts is to allow the nuts to ripen on the trees and collect the fallen nuts from the ground at regular intervals.

Notwithstanding that in addition to the reasons stated above it is also cheaper to harvest the nuts by allowing them to ripen and fall from the trees as they reach maturity than to pick the nuts from the trees, the latter custom is prevalent in most coconut-growing countries.

In the Philippines the green nuts are gathered from the trees either by the use of knife attached to the end of a bamboo pole by means of which the stems are cut or notches are cut in stepladder fashion in the trunks of the trees for the pickers to ascend the trees. In order to prevent undue decay such steps as are made should be cut in a slanting fashion so as to shed water; they should never be cut deeper than absolutely necessary. The picking of the nuts may be done at intervals of eight to ten weeks.

Copra made from immature coconut meat has a tendency to reabsorb water after drying; it molds and sours. Therefore, where the green nuts are harvested as in the Philippines, in order to produce a good grade of copra, the nuts should be piled up in a dry place to "cure" for about a month before husking.

The best way to ripen or cure the nuts is to construct curing racks on which to place the nuts. These may be made of bamboo in several tiers, one above another, the "floors" in each tier about 57 centimeters apart and the bottom "floor" about 10 centimeters above the ground to allow free circulation of the air.

Owing to close spacing and no cultivation the average annual yield per tree in the Philippines is estimated at 25 nuts, in extreme cases running perhaps not over 10 nuts per coconut tree per year, and then the nuts

are small and a large number is required to make a given amount of copra.

In a plantation located with due regard to the requirements of the coconut, and well managed, the yield may be conservatively estimated as follows:

Seventh year, 15 nuts; eighth year, 25 nuts, ninth year, 45 nuts; tenth year, 70 nuts.

After this the last year's crop may be maintained annually for at least 50 to 60 years.

There may be a light crop even the 6th year, but the prospective planter should consider this as a windfall rather than otherwise. On the other hand some planters consider an average estimate of 70 nuts per year per tree on and after the 10th year as below just expectations. If we figure on a distance of 10 meters apart of 100 trees to the hectare this would give an annual crop of 7,000 nuts, while a yield of 60 nuts per tree would give a return of 6,000 nuts per hectare.

In Mindanao, on well cared for estates, 3,270 nuts of the Romano variety are required to make 1 metric ton of copra, while of the smaller nuts produced further north, from 4,000 to 5,600 nuts, of the variety commonly grown in Laguna and Tayabas known under the name "Laguna," are needed to make a ton of copra. In this connection, it may be stated that in Samoa and Trinidad, 6,000 and 6,450 nuts, respectively, are required to make a ton of copra.

COPRA AND COPRA MANUFACTURE.

Copra is the dried meat of the coconut, and at present constitutes the principal and the most important article of export derived from the coconut palm. The meat is dried in the sun or in artificial driers.

More recently the Bureau of Science, Manilla, has experimented with a method for the preparation of copra by treatment of sulphur dioxide gas, and allowing the meat to dry without addition of artificial heat.

In order to successfully resist deterioration from molds and bacteria and so produce a first-grade oil and secure the highest price obtainable in the market, copra should be made only of fully matured or "cured" nuts; it should be thoroughly dried so as to make a clean product, containing not more than 6 per cent. of water. Ordinary sun-dried copra contains about 9 per cent. and "tapahan," or smoke-dried copra, frequently exceeding 20 per cent. of moisture, a condition that, particularly in long storage in a moist, damp atmosphere, is all too favorable for the growth of molds, the foremost enemy of improperly prepared and improperly cared for copra, and the formation of fatty acids at the expense of the oil content.

After the nuts are properly cured they are ready for husking, the first operation in copra making.

Many attempts have been made to invent a mechanical husker, and several power-driven huskers have been devised and placed upon the market. Whatever the reason, such as have been introduced into the Philippines do not seem to have proved satisfactory and none are now in operation, so far as the author is aware. All the husking in the Philippines is done by hand. Considering that an experienced husker can handle 1,000 or more nuts per day, at the present price of labor it seems unlikely that power huskers will supersede manual labor for this process for some time to come.

The husking by hand is a very simple operation and consists of the use of an ordinary sharp plow-point pointing upward, set into a heavy block of wood, and so high that the point is a little above the knees of the husker. The photograph illustrates the operation better than could any written description.

After husking, the nuts are cut in halves by a sharp blow with a bolo, which, where the copra is sun dried, are placed face up in the sun to dry for a short time until the meat separates from the shell. After this has been attended to the drying of the meat is completed in the sun and the copra is then ready for the market.

A few artificial copra driers are now being operated, but the amount of copra thus produced is still insignificant and for all practical purposes all the copra in the Philippines is still sun dried or smoke-dried. In the sun drying the halved nuts are first spread on the ground; as the drying proceeds the meat is collected and placed on palm-leaf mats. The smoke or "tapahan" dried copra is produced by placing the meat on bamboo screens over a crude furnace from which the heat and smoke rises and passes through the bamboo screen and meat. A high-grade product suitable for the manufacture of edible products cannot be made with the "tapahan" drier, which cannot be too strongly condemned.

In the rainy coconut districts artificial driers will of course be imperative, but in those regions where the bright days are sufficient to render the perfect drying of the meat practicable, for instance in Cebu and Bohol, sundrying is particularly well adapted to the needs of the small, individual producer, for sunlight and heat may be had without the asking. However, in order to produce a better and cleaner copra, the present custom of spreading the coconut meat upon the ground should be discontinued. Trays should be made of bamboo, upon which to place the meat for exposure in the sun the same as is done in drying fish.

Various local methods are used for the extraction of oil, nearly always from the fresh nuts, from which the meat is removed with the aid of steel burrs operated by a treadle.

The meat is then heated and the oil expressed. All methods employed are crude and much of the oil is lost.

In modern mills 65 to over 70 per cent. of the oil can be extracted according to the grade of copra.

This is a by-product of the modern oil mill, rather than of the coconut palm, which has made its appearance in the Philippines since the establishment of the coconut-oil mills. Where the oil is hydraulically extracted and the copra is sun or machine-dried the copra meal makes an excellent feed for domestic animals and an excellent fertilizer.

Coir is a fiber obtained from the husk of the coconut and is used for various purposes wherever the coconut is culitvated to any appreciable extent. As an article for export coir is manufactured principally in Ceylon, India, the Laccadives, and the Federated Malay States. Coir was formerly of slight importance; but with the invention of coir manufacturing machinery, it has found useful employment in many ways. It is now used in making cordage, rugs, mats, brushes, upholstery, brooms, mattresses, for caulking, and various other purposes.

The best grade of coir is obtained from the nuts before they are ripe, but the revenue from copra is so great as compared with that from the best coir that the production of coir at the expense of the copra is unprofitable; hence coir will only be a by-product so to speak, of copra, and at present it is not even that in the Philippines, practically all husks, except a few that may be used locally, being allowed to go to waste or used as fuel. So far as known, coir machinery has never been introduced in the Philippines, though it seems reasonable that if the conversion of husks to coir is profitable in other coconut-growing countries, it would be so here if properly handled. As the leading copra-producing country in the world it would seem logical that the Philippines should also take a lead in coir production and export.

Most of the coir is produced by first retting the husks in salt water and then beating them with mallets, but within recent years fiber-extracting machinery has been invented that is said to be quite satisfactory.

According to the estimate, the coconut husks from one hectare of coconuts at the yield stated previously would produce per year 490 kilos of yarn and 70 kilos of brush fiber.

Among other possible by-products are buttons from the coconut shells.

It has been found that the fermented milk can be utilized in the coagulation of latex in place of acetic acid in the preparation of rubber. The burned shells might be utilized as bone char in sugar manufacture.

Palm wine and arrack are obtained by cutting the immature inflorescence of the coconut and collecting, fermenting, and distilling the exuding sap that otherwise would have served for the development of the flowers and to form the nuts. The production of palm wine and arrack is of considerable local importance in most countries where the coconut is at all extensively cultivated.

From experiments made by Gibbs in this Archipelago, a tree will produce from 0.35 to over 1.40 liters of sap per day. From one to three flowerspikes are tapped at a time, the sap flow from an inflorescence continuing usually from 25 to about 40 days. The sap is gathered two or three times daily by the collectors, who at the same time make a fresh cut off the inflorescence in order to increase the flow of sap. Bamboos are tied between the palms to serve as bridges for the sap gatherers.

Excellent vinegar is also made from the fermented palm sap, but the utilization of the sap for this purpose is of slight importance.

Sugar may be obtained from the unfermented palm sap. This also is purely local industry which is of no importance in the world's trade and needs only passing mention.

Practically all the nuts produced and exported in the American tropics are consumed in the manufacture of desiccated or dried, coconut meat which is put up and used in various ways for culinary purposes.

Being extensively used as food and drink by the native inhabitants in all countries where it is grown, the coconut is not so appreciated by the Caucasian resident in the tropics as it deserves to be considering its nutritive and gustatory qualities.

No one needs an introduction to the fresh milk or the jelly-like meat in the immature coconut, but the following hints may be found useful.

Coconut cream may be prepared by grating the fresh meat, which is strained with a little water through a cheese cloth. This cream may be used in various ways in preparing puddings, cakes, etc., the same as dairy cream and it imparts a delicious flavor to the dish.

Delicious ice cream and sherbet may be made from the grated nut. The nut may also be used as a filling for pie. Properly made coconut candy is unexcelled.

The major uses of the coconut tree and its fruit have been discussed at more or less length, but in addition it has found employment in various other ways. Few plants, if indeed any, are so serviceable in so many ways to primitive man as the coconut. The roots furnish a dye; the trunks are used for building material; the leaves are employed for thatching; the midrib serves in making baskets, brooms and brushes; the husk may be used as a scouring brush and together with the shell as fuel; the shell is also made into cups, ladles, spoons and other utensils. Numerous other uses of the coconut palm might be enumerated.

Perhaps there is no better evidence of the recent entrance of the coconut into the group of important agricultural crop plants than the fact that even in publications not a score of years old the coconut is spoken of as being one of those few plants that seemed to be nearly if not quite immune to plant pests. However the coconut has only served to emphasize the fact that scattered plants, due to their isolation and the difficulty of transmigration of pests from plant to plant and also because of lack of subsistence, make immunity of a species apparent rather than real. As large areas are planted to a species its inherent enemies find more favorable opportunity for development and multiplication, and a fungus, bacterium or an insect pest that, figuratively speaking, had existed since the beginning of time, merely remained unnoticed until its host became of sufficient industrial importance to necessitate its extensive cultivation. The coconut, in common with all other cultivated crops, has its quota of fungous, bacterial, and insect pests, some of which, if no measures were taken for their control, would rapidly wipe out coconut growing as an agricultural enterprise or reduce the profits to a minimum.

The perpetuity of summer with no marked seasonal changes to interrupt the development of plant pests, renders these vastly more dangerous in the tropics than in the temperate zone, a matter that might profitably be pondered, both by the planters and the Government institutions charged with looking out for the welfare of the agricultural industries of a country. There should be a stringent plant quarantine as protective measure against the invasion of foreign plant pests, and the law-making bodies should make adequate provisions of compulsory sanitary measures interiorly. It may be positively stated that with or without such laws, if in the former instance not enforced, considering the serious nature of some of the coconut pests, coocnut growing will never attain and maintain itself as a truly great industry anywhere. This is peculiarly true of the Philippine Islands, where the three greatest coconut evils have already made their appearance—the budrot, the uang, and the dalipos. The people should be educated to understand the dangerous nature of the coconut pests and to the need of their control and eradication.

High Vacua and Their Measurement*

THE extraordinary high vacua claimed for modern air pumps, and especially for the Gaede diffusion air pump[1] make one wonder in two respects. How is it possible, one asks, to produce a vacuum of the order of 10^{-8} mm. of mercury in a pump which works with mercury vapor? And how can we measure the pressures of gases so highly rarefied? Exceptionally high vacua can undoubtedly be obtained with the aid of diffusion pumps, for they are displacing all other means of producing high vacua—except gas absorption by cooled charcoal, which has its own wide field of utility. But how are we sure that the rarefaction is really pushed beyond the limits formerly attainable? The appearance of the electric discharge through vacuum bulbs changes as the gas pressure is reduced; comparative estimates of the gas pressures can be based upon such observations. For actual measurements, however, physicists have practically been relying upon the vacuum gauge which Professor Herbert McLeod, then of

*From Engineering.

[1]Described in *Engineering*, August 25, 1916, page 169; and January 28, 1917, page 83.

Coopers Hill College, described in the *Philosophical Magazine* in 1874. The idea of this gauge is that a known volume of the gas under test is, by a rising column of mercury, cut off from the rest of the gas and condensed into a smaller space in which its pressure is measured. Pressures as low as 1×10^{-5} mm. of mercury have been determined with the aid of the McLeod gauge, which has indeed served as checking instrument in most of the recent researches we are going to notice. But the apparatus has to be of inconvenient size for the determinations of high vacua; the mercury of the gauge itself contributes an uncertain percentage to the gas pressure to be measured, an allowance has to be made for other gases given off by the apparatus at very low pressures, and this factor can hardly be eliminated by submitting the aparatus to a heat treatment, possible with other gauges.

Other types of gauges, especially mercury-free gauges, have hence been proposed. The Bourdon gauge, in the shape of a glass spiral, was tried by E. Ladenburg and E. Lehmann in 1906. K. Scheel and W. Heuse, investigating high vacua and their production in 1909, separated two chambers, the one connected with the apparatus, the other maintained at constant gas pressure, by a copper diaphragm, and measured the interference bands produced by the deflection of the diaphragm. Studying since 1906 the friction on gases at low pressures by means of vibrating discs, J. L. Hogg found a simple relation between the decrement of the vibrations and the gas pressure. M. von Pirani, 1906, based his method on the determination of the electric resistance of an electrically-heated wire stretched in the gas. At low pressure the thermal conductivity of the gas is a function of the gas pressure; when the volts at the wire terminals are kept constant, the heat loss by conduction through the gas decreases as the pressure is lowered, and with a bridge arrangement the pressure can be measured by keeping constant either the temperature of the wire, or the current flowing through it. The Pirani gauge was simple, but did not prove very sensitive; C. F. Hale improved the sensitiveness, and the gauge is particularly suitable for lamp measurements, but it has especially to be calibrated for the particular gas in the bulb, since the thermal conductivity of a gas depends upon its nature. The molecular gauge of S. Dushman, 1915, is the outcome of Langmuir's researches on thermoionic currents in high vacua. The gauge consists of a glass bulb in which a metallic disc is rotated by producing a rotating magnetic field outside the bulb; a second disc carrying a mirror is suspended within the bulb above the first disc. Good work has been done with this gauge also in low-temperature research; the mechanism is elaborate, however, and though all its parts bear temperatures up to 300 deg. C., the relatively large masses of metal are not desirable for high vacua. In 1916 O. E. Buckley proposed an ionisation gauge, consisting of a kathode (Wehnelt kathode or incandescent filament), an anode and a collector between these electrodes; he determines the ionisation of the gas produced by the electrons given off by the filament which is charged to several hundred volts, his actual gas pressure measurement depending upon the ratio of the collector current to the anode current. The method can be modified in various ways. In the most recent paper on the Production and Measurement of High Vacua (*Physical Review*, July, 1918), J. E. Shrader and R. G. Sherwood, of the Westinghouse Research Laboratory, state that finding the Buckley gauge, which has to be established for each gas and vapor, not very sensitive nor very constant in its readings, they had devised a new form of the Absolute Manometer, which Professor Martin Knudsen, of Copenhagen, most fully described in the *Annalen der Physik*, volume 32, pages 809-842, 1910. This gauge has much been used of late.

The paper quoted, it will be noticed, was written before the days of the diffusion pump, but later communications followed, and Knudsen dealt in 1917 already with the effect of the tension of the mercury vapor in mercurial pumps. Knudsen directly measures the forces of repulsion set up by the molecular bombardment between two parallel plates of unequal temperatures which are mounted close to one another in the rarefied gas. These forces determine the total pressure due to any gas or vapor present in the space under examination, and Knudsen himself speaks of them as radiometer forces, as it has been known since 1874, that it is the bombardment by the molecules of the residual gas in the Crookes radiometer which turns the vanes. Though there is quite a literature on the radiometer, it does not appear that the radiometer forces were ever utilised for quantitative pressure measurements, and the radiometer hardly lent itself to such measurements. For this purpose accurate temperature measurements would have been required, and there was, as Knudsen points out, uncertainty as to the exact way in which the kinetic laws should be applied to the radiometer. Maxwell considered that there would be very little effect between the central parts of two parallel discs, because the temperatures varied uniformly between the discs; stress would only arise from inequality of temperature in the gas near the edges of the discs. Johnstone, Stoney and Fitzgerald suggested that there must also be a disc effect, and not merely an edge effect. Knudsen sides with the latter.

Gas molecules rebound from a warm wall with a greater velocity than from a cold wall. When there is temperature equilibrium between the molecules and the wall (solid or liquid), the direction in which the molecules rebound is independent of the direction of incidence, and the average velocity of the molecules remains unchanged, according to Knudsen. But when there is no temperate equilibrium, *i. e.*, when the molecules oscillate between two parallel plates of unequal temperature, both the direction and the velocity of the rebound are changed. As long as the distance between the two plates is very small compared to the free path of the gas particles, the force of repulsion between the two plates depends only upon the gas pressure and the temperature difference; when the latter and the force of repulsion are known, the gas pressure can be deduced by a simple formula. This formula is $p = 2 \mathrm{K} / \left(\sqrt{\frac{\mathrm{T}_1}{\mathrm{T}_2}} - 1\right)$, where p is the gas pressure in dynes per sq. cm., K the force of repulsion in the same unit, and T_1 and T_2 indicate the absolute temperatures of the two plates. For small differences of temperature the formula may be simplified into $p = 4 \mathrm{K}\ \mathrm{T}_2/(\mathrm{T}_1 - \mathrm{T}_2)$. Knudsen deduced these formulae from the kinetic theory and confirmed them by experiments with hydrogen, oxygen, air, carbon dioxide and mercury vapors, and for gas pressures of less than 0.003 mm. of mercury, or less than 4 or 5 dynes per sq. cm. The formula does not hold for pressures higher than 0.003 mm. When a constant c is introduced, so that the numerator of the first formula becomes $2 \mathrm{K}c$ (leaving out the denominator), c converges towards the value 1 as the gas pressure approaches zero. With increasing pressures c grows exponentially, and c is (equal pressures presumed) smaller for hydrogen than for the other gases, and c also varies but slightly with the distance between the plates and the temperature; in the case of oxygen the relations appear to be somewhat less simple. Knudsen's experimental proof followed three lines: (1) At ordinary temperature his gauge agreed with the McLeod gauge which, as already stated, indicates the pressure of the gas together with the pressure of the mercury vapor at the respective temperature; (2) the pressure of the gas was varied by introducing small measured volumes of the gas into the apparatus, the pressure variations agreeing with the McLeod readings and with Mariotte's law; (3) a little mercury was admitted into the apparatus, the air evacuated, and the mercury then condensed by cooling the glass walls; the gauge readings went down in accordance with the diminution of the mercury vapor pressure.

In its simplest form the Knudsen gauge consists of an electrically-heated strip or plate of platinum, in front of which, at a distance of about 1 mm., a piece of foil is suspended as vane; the deflections of the vane are observed by the aid of a mirror and telescope. To study edge effects, the plate was cut up into several narrow parallel strips, or the plate was given the form of a copper cylinder with horizontal axis, surrounded by a longer concentric copper cylinder; the apparatus was also arranged like an electrometer, two vanes, each covering half the plate, being used, the one in front, the other behind the plate. Very good results were also obtained with a water-jacket apparatus; there is an inner glass tube in which a piece of mica is axially suspended as vane; the tube is sealed into a wider glass tube, itself surrounded by a water-jacket, and the tubes are connected with the vessel to be evacuated. In this case the warm gas molecules in contact with the outer tube reach the vane through a rectangular slit provided in the inner tube. The temperature difference $\mathrm{T}_1 - \mathrm{T}_2$ was varied between 8 deg. and 250 deg. in the various experiments. The Knudsen gauge of Shrader and Sherwood, which we mentioned above, is more elaborate. It is a glass bottle with short neck, 9 in. high, 2 in. diameter, containing a C-shaped glass rod from which the parts are suspended. The heating strip is of platinum, 0.018 mm. thick, 7.5 mm. wide, 18 cm. long, and is folded so as to form a flat horseshoe, about 7 cm. long; it is kept straight by tungsten wires and is connected by platinum wires to the wires leading to the potentiometer. The moving vane is a plane, rectangular frame of aluminium foil, 0.0076 cm. thick, 0.5 cm. wide, the outside dimensions of the frame being 4 cm. by 3 cm.; an aluminium wire prevents warping of the foil, which carries a mirror; the suspension is by a tungsten wire of 0.0005 in.; we give the dimensions in millimetres, centimetres and inches, as in the paper. The distance between the strip and the vane, about 1 mm., can be adjusted from outside by means of a magnet. The mirror of the vane is a small piece of platinised glass, baked at 500 deg. C. In some experiments the platinum strip was heated up to 525 deg. C. absolute. In comparative tests against a McLeod gauge of 750 cub. cm. capacity, the two gauges agreed within 10 per cent. for pressures of 3×10^{-5} mm.; the lowest pressure measured by Shrader and Sherwood was 2×10^{-5} mm. Silver mirrors first used did not stand the heat treatment to which the gauge was submitted.

Electric heating of the strip offers the advantage that resistances can be substituted for the temperatures in Knudsen's formula, and that temperature measurements, needed for the water-jacket apparatus, are not required. Shrader and Sherwood give the formula in electric terms, and they also describe an improvement of the mercury diffusion pump which seems to deserve notice. As regards the theory of the diffusion or condensation pump and the rebounding of molecules from hot walls, about which Knudsen and Langmuir are not in accord, we must refer to our previous articles.

Acetic Acid

Among the many new industries which have been developed in Canada during the war, none has attracted more interest than the development of the process used at Shawinigan Falls, Que., for the synthetic manufacture of acetic acid. Although much has been written during the last two years regarding this plant and process, a brief summary may not be out of place.

The process consists of (1) the conversion of acetylene gas to acetaldehyde in the presence of sulphuric acid and a mercury salt. The acetylene gas used in this process is generated at what is probably the largest generating station in the world. 2. The conversion of the acetaldehyde to acetic acid by oxidation in the presence of a catalyst. 3. The catalytic decomposition of glacial acetic into acetone.

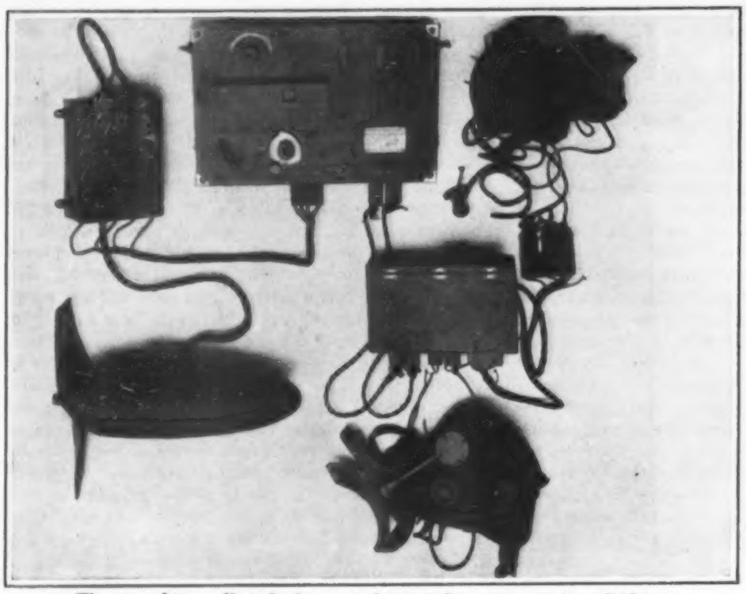
In each process the crude materials are carefully distilled, so that only pure products are used for the next step, *i. e.*, refined acetaldehyde is used for the manufacture of acetic acid, and the glacial acid is used in the final process.

Another feature is the purity of the crude acid obtained by this process. This crude acid does not contain any of the impurities which are always present in the crude acid made by the wood distillation process. It is quite free from sulphuric acid, tar, or resinous matter, and is absolutely water white in color. Such purity is a decided advantage in the manufacture of colors, etc., and also when used in dyeing. It has been found by actual experience in several color manufacturing plants and dye houses that the results obtained by the use of the crude acid made by this process are decidedly superior in many ways to the results obtained by the crude acid previously used. In every case the colors have been brighter, shades and tints truer and more easily duplicated, and the results have in every way been more uniform. These results are due not only to the purer quality of the crude acid, but to its absolute uniformity.

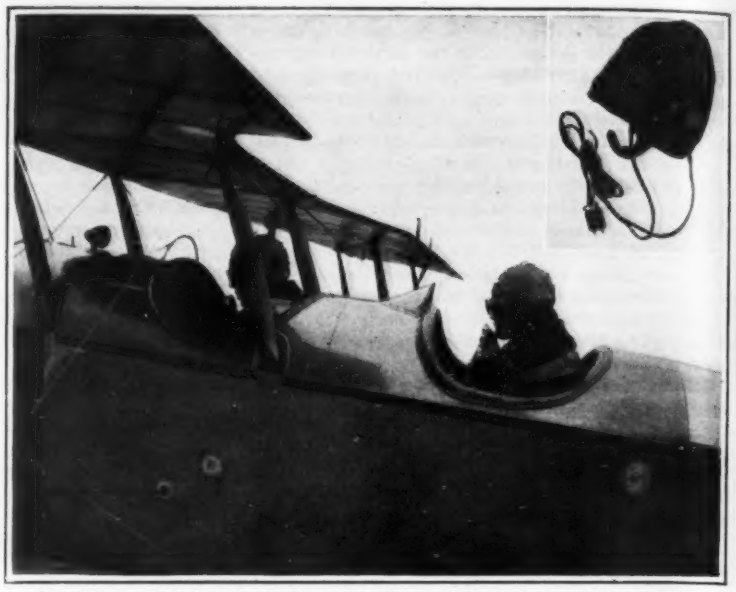
Two plants were erected for the manufacture of acetic acid by this process, each plant having a capacity of approximately 700 to 800 gross tons of glacial acid per month. One of these plants has been in operation since 1916, and has proved beyond doubt that the process is commercially successful.

Much research work has been undertaken by the chemists responsible for the development of this process, with a view to developing other synthetic materials. These investigations have proved that many other commonly-used organic products can readily be made "synthetically" from the acetylene base, and intermediate products made available in the manufacture of acetic acid. It is quite possible that at least some of the following products will be manufactured synthetically at no distant date: Alcohol, acetic anhydride, acetylene tetra-chloride, chloral hydrate, chloroform, dichlorethane, ethyl acetate, formaldehyde, monochlor-acetic acid, and paraldehyde.

Many of the chemicals mentioned above are now being made synthetically from acetylene in Europe, particularly in Switzerland, France, and Germany. While there is no doubt a certain similarity in the different developments in these various countries, those responsible for the Canadian undertaking feel certain they can meet foreign competition in this field, owing to many advantages their process has over any similar development elsewhere.—*Jour. Soc. Chem. Ind.*



The complete radio-telephone equipment for a two-seater airplane: Signal Corps standard SCR-68



Receiving a telephone message on a plane; the insert shows the special helmet designed for this service

Radio Telephony—III*

A Final Survey of the Problems Solved and the Future Rôle of Wireless Speech

By E. B. Craft and E. H. Colpitts

[Concluded from Scientific American Supplement, No. 2260, Page 271, April 26, 1919]

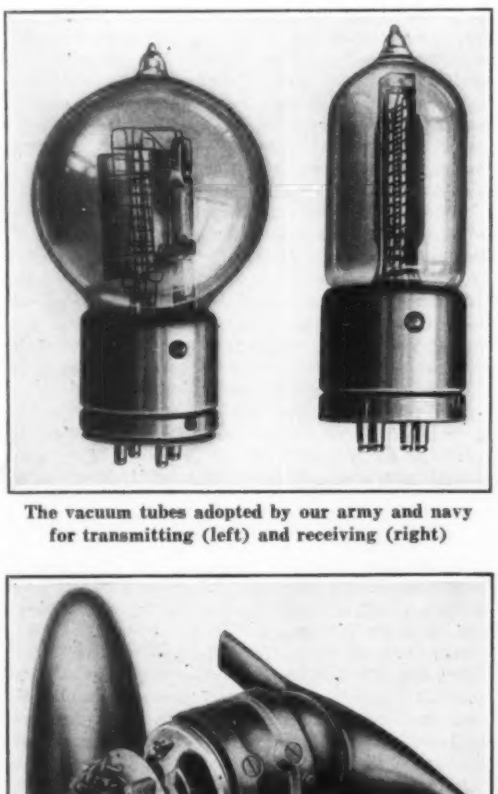
Since the first experiments the trailing wire antenna had been employed and wave lengths of from 200 to 500 meters were used. It was realized that a long trailing wire antenna was not well adapted for use on military airplanes for tactical reasons, and it would be very desirable to limit the physical dimensions of the radiating system. This, of course, implies a corresponding reduction in the length of wave radiated if an efficient system is to be used, and steps were taken to design such a set. There is no difficulty in securing extremely short waves with the vacuum tube oscillator but there is some difficulty in designing a very compact set, with wave length adjustable over a considerable range and containing amplifiers and modulators, and at the same time avoiding excessive losses. In October, 1917, some laboratory sets were made for wave lengths of the order of 70 to 150 meters, and early in 1918 the Signal Corps requested the development of a short wave set. This was built in April and was electrically essentially the same as the longer wave sets except for minor changes due to the use of higher frequencies of the order of 4,000,000 cycles.

Trials of this system were made at Camp Alfred Vail at wave lengths of 60 meters and above. The antenna first used was a very short structure on the top of the plane with two wires extending to the tail. This antenna had a natural wave length of 32 meters and a resistance of only one ohm. To increase the radiating qualities the rear portion or the antenna was raised and the resistance thereby brought up to nearly 3 ohms at 75 meters. This structure did not materially increase the head resistance of the plane and did not interfere with its operation. As described later, this form of antenna was soon replaced by another.

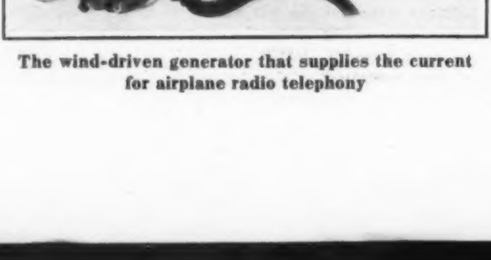
The use of short wave lengths brings forward prominently the problem of location of component parts of the set in the plane, for a few unnecessary feet of connecting wire carrying these high frequency currents may cause the failure of the set. For this reason considerable thought was given to the question of location of transmitter and control box. In the photograph showing the final form of these short wave sets it will be observed that the multiple unit plan of assembly has been carried further than heretofore, and this was due to the fact that difficulty was encountered in mounting the SCR-68 type set in the single place combat planes.

RADIATING SYSTEMS.

The whole subject of proper radiating systems for use on planes was one to which more time should have been applied than was available at the time of development and manufacture of the first apparatus. A considerable amount of work, however, was carried on and valuable data obtained. This work was started in the summer of 1917 at Langley Field, and was later transferred to Camp Alfred Vail, N. J. The work was in charge of Mr. A. A. Oswald under the direction of the Signal Corps, and resulted in the accumulation of a considerable amount of useful data on many types of antenna. There are three important conditions to be met in designing an antenna for use on airplanes. Such an antenna must be an efficient radiator; must not be directive; and must not interfere with complicated evolutions of the plane. The third condition practically prohibits the use of a long trailing wire with a weight, because of the danger of fouling the propeller. This type of antenna is also quite directive.



The vacuum tubes adopted by our army and navy for transmitting (left) and receiving (right)



The wind-driven generator that supplies the current for airplane radio telephony

The details of this antenna investigation should properly be covered in a separate paper. It may be well to state, however, that the best system, all things considered, was found to consist of two short unweighted wires, one from each wing tip. The two wires were joined in parallel above the fuselage, and worked against the conducting portions of the plane as a counterpoise. It was found that the use of one such wire as antenna and the other as counterpoise was not good.

In Fig. 11 the distribution of intensity of radiation is shown with the single long trailing wire and the two wire type of antenna.

IGNITION INTERFERENCE.

Another problem arose when sets began to be installed. This was that of noise in the receiving sets due to the engine ignition, and was very serious in some cases. Its solution was complicated by the fact that it was not allowable to alter the plane equipment in any way, for instance by changing the position of one magneto to secure greater shielding, but it was found that by covering the ignition wires with a flexible conducting tube grounded at intervals this trouble could be practically eliminated.

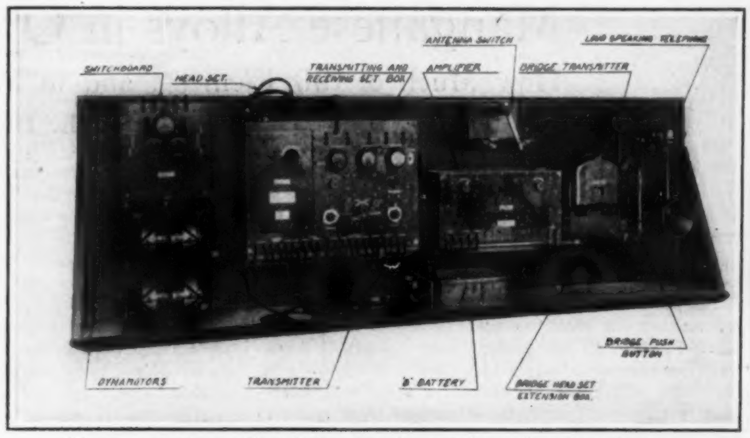
It was found that in some cases the ignition spark started in the ignition system high-frequency oscillations which were of proper frequency to affect the receiver. This happened on the submarine chasers, which are driven by gasoline engines, and the trouble was remedied by inserting small iron-core choke-coils in the ignition leads to change the frequency of the oscillations. It is obvious that the "radio signals" sent out by the ignition spark are many millions of times more intense than those to be received and it is remarkable that they do not entirely prevent reception. As a matter of fact, successful airplane telegraphy has been carried on in an experimental way by using the ignition magneto as a radio transmitter.

SUBMARINE CHASER EQUIPMENT.

During the war important use has been made of the wireless telephone in connection with Naval work. Small 110-foot craft had been largely employed in connection with anti-submarine operations. In order to make the most effective use of the various listening devices, and to co-ordinate the operations of the various units, it is very necessary that instantaneous and direct communication be established at all times. Under the direction of the Special Submarine Board of the Navy Department, modified forms of radio telephone equipment were developed for this purpose. Early in November, 1917, the first practical trials were made, and satisfactory operation between chasers approximately five miles apart was obtained. These

*Presented at the Convention of the Amer. Inst. of Elec. Engs. in New York. Copyright by the Institute and reproduced by permission from its Transactions.

Radio telephone transmitting and receiving set for ground use



The two-station radio telephone equipment for submarine chasers

trials demonstrated the extreme value of this means of communication and sample equipments were immediately dispatched overseas for further trials under actual war conditions.

The circuits of this set are practically the same as the airplane equipment, except that power is obtained from small dynamotors operated from the 30-volt storage batteries with which the chasers are equipped. The set itself is located in the radio room, where it can be attended to by the regular radio operator. A telephone transmitter and receiver is, however, located in the pilot house so that the commanding officer can hold direct conversation with other vessels. The radio operator monitors the conversation and performs all tuning operations, thus leaving the commanding officer free to use the radio telephone as an ordinary wire line, except that he must press a button located at the side of the telephone when talking. The ordinary telephone head set is supplemented by a loud-speaking telephone receiver, which makes it possible for incoming signals to be heard without the use of head gear. We show an assembled view of the various elements that go to make up a standard submarine chaser equipment. To provide sufficient energy for operating the loud speaking receiver a three-stage amplifier connected to the output side of the radio set is required. It is possible to connect the receiving portion of the radio set to either the ordinary head receiver or to the amplifier with its loud speaker.

This equipment has an effective operating range of about ten miles when used on the 110-foot submarine chasers. One feature not incorporated in the airplane sets consists of a wave-length control gear by means of which the set can be operated on any one of five different wave lengths, ranging from 250 to 600 meters. This permits of a certain amount of selective operation within a chaser squadron.

A number of problems were met with in connection with this particular application not the least of which was the suppression of electrical disturbances in the antenna system due to the ignition system of the three propelling engines. Several thousand of these sets have been produced, and practically all submarine chasers sent overseas have been equipped with this apparatus. This apparatus is also being used for short range work on other types of naval vessels, with eminently satisfactory results. Modifications of the airplane type of equipment have also been made for use on naval seaplanes. For some classes of service the demand for longer range work has made necessary the employment of more powerful types of vacuum tubes.

The foregoing covers the most extensive application of vacuum tube radio telephony, the same general type of circuit and apparatus being used for short range telephony and telegraphy on land and water and in the air. For reasons already mentioned, quantity production has been limited to the earlier models, in spite of the fact that investigations carried on during production have indicated many changes which would improve the electrical and mechanical efficiency of the apparatus.

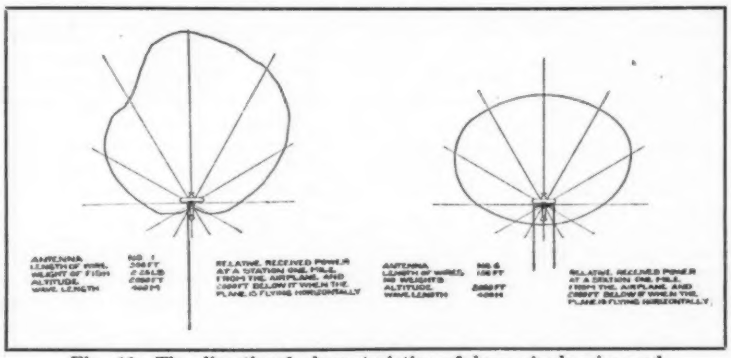
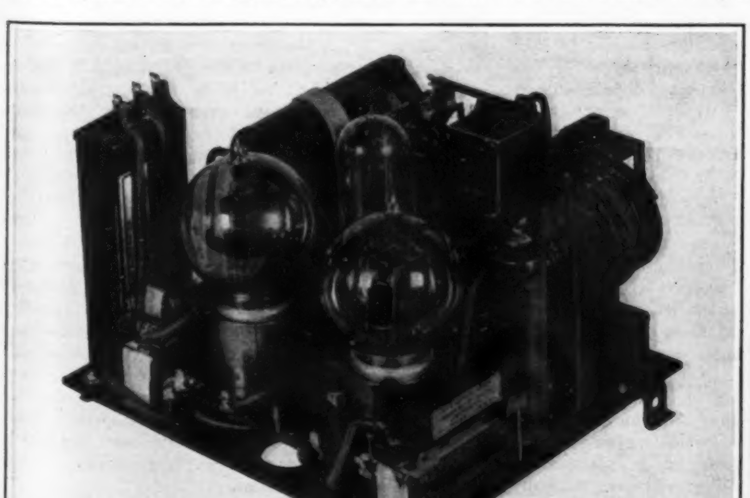


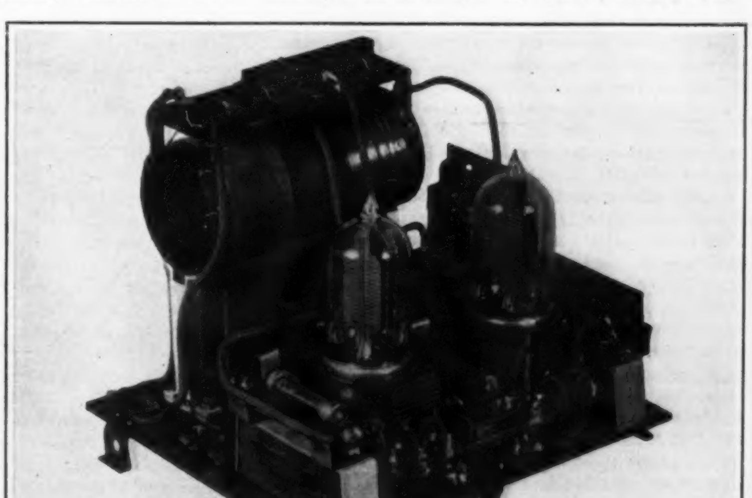
Fig. 11—The directional characteristics of long single-wire and shorter double-wire antennae

THE FUTURE OF RADIO-TELEPHONY.

The possibility of communication by speech between any two individuals in the civilized world is one of the most desirable ends for whch engineering can strve. For this reason it is particularly desirable to form some opinion of the part which radio telephony may play in securing this universal service. It is clear that the elimination of the Morse operator, which is accomplished by the use of radio telephony rather than radio telegraphy, is necessary for universal and direct communication.

Radio telephony and wire telephony offer several sharp contrasts. The latter requires fixed channels of communication whose construction and maintenance necessitates an accessible path between stations, but the results obtained include secrecy, power efficiency, selection of a desired station and freedom from interference. A large item of expense is the line. On the other hand radio telephony requires neither fixed nor accessible channels and no cost at all for line construction and maintenance, but it is non-secret in the practical sense of the word, its power efficiency is low, selection is at present not practicable except in a limited way by wave length, and freedom from interference is not at present an attained fact. Thus while the two systems may be contrasted they are not comparable but each is useful in its own field. It is easy to see that radio telephony can never compete with wire telephony in densely populated districts, while wire telephony is a physical impossibility at sea and in the air. Fortunately, however, the connection of a wire system to a radio system is no more complicated than connecting two wire lines by means of a repeater and therefore these two fields, although distinct, are adjacent. Leaving aside for the moment the particular methods by which radio telephone communication is to be carried on, it is clear that the establishment of communication between two given individuals will be most efficiently realized through the use of a combination of wire transmission on a network extending over perhaps 99 per cent. of the stations and radio transmission to those relatively few stations to which it is either impossible or impracticable to build lines. These stations will be of two kinds: moving, such as ships, airplanes, trains, trucks; and fixed but inaccessible, such as on islands, in deserts and in very sparsely settled regions.





The interior construction of the short wave transmitting and receiving units

Manganese Alloys in Open-Hearth Steel Practice*

How Much of this Element, and in What Form, Represents the Best Usage?

By Samuel L. Hoyt, Bureau of Mines

Broadly speaking, the purpose of the manganese investigation was to consider the most suitable means of utilizing domestic manganese, thus relieving to the greatest extent possible our shipping of the burden of importing manganese ores. It was not held that any decided shortage of manganese was imminent, but rather that every legitimate means should be utilized for making our ship tonnage available for European service. Although this country has considerable deposits of manganese, it occurs largely as a low-grade mixture with either iron or silicon or with both, consequently the open-hearth investigations were made to determine the extent to which domestic or low-grade alloys could properly be substituted for high-grade alloys without materially impairing the steel production either as to quality or quantity. Moreover, it was held that such an extensive investigation of this important step in the manufacture of steel would undoubtedly yield valuable results to the steel industry as well as contribute, in no small way, toward directing future investigations in the same field.

The evolution of the details of a definite experimental program from the statement of the general problem, considering the time element and the many and varied factors involved, was not lightly undertaken nor finally reached without due consideration of competent metallurgical advice. After making a preliminary survey, it seemed important to determine (a) the conditions in open-hearth practice that would lead to a conservation of manganese, both during the working of the heat and in making the final additions; (b) the most satisfactory metallurgical conditions for the use of manganese in the form of low-grade or special alloys; and (c) the effect on the finished steel, both as to quality and "condition," of the various methods and processes studied.

It was decided to determine slag and metal compositions during the refining of the heat and to observe the temperature each time a sample was taken, the latter to determine, if possible, the temperature effect. The "recovery" of manganese was to be determined from the residual and final manganese contents and the weight of the metal. To this end a sample of the finished steel was taken during teeming. By taking three such samples, one at the beginning, one toward the middle, and one at the end of teeming, tests for uniformity were possible. This practice was generally observed throughout the investigation. The data obtained were also supplemented by the plant records covering given heats as well as by personal observation during refining, pouring, and teeming.

When it came to planning steps that should be taken to determine the quality and "condition" of the steel, it was found that no definite and well-proved method, which could be adopted, was available. It is quite true that the open-hearth melter knows whether his heat is in proper condition but what was needed was a quantitative estimate of "condition." Without attempting to enter upon a discussion of the physical chemistry of a heat of molten steel, it may be said that the condition of a heat of steel must depend, aside from the temperature, upon the composition of the steel in those substances that affect the "condition." Of these there are two kinds: (1) Those that promote "openness," or the gases, which again may be classified as (a) gases that are products of chemical reactions, being in so far as we know, CO and possibly CO_2, and (b) gases that are absorbed from the furnace gases such as H, N, CO and CO_2; and (2) those that promote "soundness," such as the reducing and solidifying agents, C, Mn, Si, and Al.

In general it is held that Mn, Si, and Al inhibit the chemical reactions producing CO by reducing (or partly reducing) FeO, the principal constituent that produced the reactions. In this statement only the metal bath is considered and the FeO, and not Fe_2O_3, is held to be in solution in the steel. According to this idea, reducing action on a slag containing Fe_2O_3 would produce FeO, part of which would enter the steel to react later with C, Mn, and other reducing agents present. The reduction of FeO, then, is the principal means of "settling up" the liquid steel and it is for this reason that Mn is added in the finals. It is also held that Si and Al produce solidity in the finished steel, aside from reducing FeO and CO, either by keeping the gases H, N, etc., in solid solution, or by preventing the dissociation of the compounds of those elements and iron.

*War Minerals Investigations Series, No. 11.

The obvious procedure to get a quantitative estimate of the "condition" of the steel, considering both the behavior of the molten metal and the character of the ingot, would be to determine the amounts of the constituents in each of these two groups and to weigh one set against the other. Even this procedure would not, at present, lead to results that could be interpreted with entire confidence, even though there were no uncertainties in the analytical methods, inasmuch as we do not know the quantitative effect of each constituent, either by itself or when associated with other constituents in varying amounts. In view of this lack of fundamental data, it was decided to make the analyses and use the results in a qualitative way, at least, to compare the different practices investigated.

THE FUNCTIONS OF MANGANESE.

During such a critical period as that now passed, the question might be raised as to the possibility of eliminating manganese from steel making. This point was duly considered but it was at once held that the use of manganese is not merely an expedient, one for which some substitute might readily be used, but rather, one of the basic requirements of successful practice in working steel. It is quite true that in many cases the actual amount of manganese used in a heat of steel is greater than purely metallurgical considerations demand and any excess could well be considered as so much wasted.

It may be well to review briefly the important functions of manganese as they bear directly on both of the points mentioned above. The first function of manganese, broadly considered, is to refine and "settle up" the molten bath of steel. The aim here is to put the metal in a proper condition for pouring, and to produce ingots (or castings) of the desired quality and texture. While manganese is not the most efficient of the elements that can be used for this purpose, calculated from the heat of combustion of the element to its oxide, it is without doubt the most satisfactory element for the purpose on account of the excellent condition (freedom from objectionable foreign inclusions) in which it leaves the bath.

The proportion of manganese theoretically required for this operation might possibly be calculated from the amount of oxygen converted from the active form, FeO, to the inactive form, MnO. Assuming an oxygen content of 0.075 per cent. in the unsettled steel and of 0.015 per cent. in the finished steel (oxygen by the Ledebur method), the amount of manganese used in this way would be 0.2 per cent. The writer is informed by the Bureau of Standards that such a calculation is premature, owing to our lack of knowledge on the subject of "deoxidation" and the faultiness of the Ledebur determinations. However it would seem to the writer, from the work done at the Bureau of Standards, that the amount of oxygen determined is the amount present as FeO (active form), subject possibly to an error due to partial reduction of CO during the determination. At any rate, the above is advanced as at least the first approximation of the amount of manganese required simply for destroying the ferrous oxide present in the bath. The amount of manganese required naturally would vary with the condition of the bath and, in order to insure efficient "deoxidation," would be somewhat in excess of the calculated amount. A well-made heat of steel would probably not require more than 0.35 per cent. Mn.

Manganese is also desirable in steel to improve the rolling properties, in which capacity it appears to serve a dual purpose. First of all, manganese deoxidizes and refines the molten steel in such a way as to give ingots of the desired texture without robbing the steel of its hot-working properties. Thus, ingots may be rolled into finished shape without the formation, in excessive amount, of fissures or of surface defects. Other reducing agents, such as Al, and Si, are prone to leave the metal in a poor condition for rolling and forging. While they eliminate one cause of hot shortness—iron oxide—they fail to convert the sulphur into a harmless form, as manganese does, and leave behind their highly refractory oxides, both of which tend to produce poor rolling qualities. Secondly, manganese, by retarding the rate of coalescence or grain growth, renders steel less sensitive to the effects of the high temperatures used in ordinary steels, at rolling temperatures. Silicon and aluminum, on the other hand, increase, rather than decrease, the grain size of steel. The proportion of manganese required in this capacity probably does not exceed 0.35 per cent. in well-made steel.

Finally, manganese is desired in the finished steel to produce certain physical or mechanical properties or to make the steel more amenable to subsequent heat treatment.

The foregoing discussion indicates that manganese is an important factor in the steel industry. Of course, material such as "American ingot iron" can be successfully rolled, even though no manganese be added, but requires greater time and care.

It is interesting to note that manganese, coming in the periodic system between iron and the strengthening elements on one side and the hardening elements on the other, has the dual function of strengthening and hardening steel, which is not possessed by any other element.

Manganese conservation would best be obtained by eliminating the manganese specification except in case the amount of manganese present in the finished steel has some definite bearing on the properties of heat treatment of the steel. In other words, whenever only casting and rolling-mill practice (plant problems) are involved, the steel man should be allowed to exercise his own judgment as to the amount of manganese which should be used to give the most satisfactory and economical practice, and the finish and quality of the product should be controlled by adequate inspection. On the basis of Ellicott's figures[1] by reducing the manganese requirements by 0.2 per cent. in making plates and shapes and other low-carbon steel (estimated production, 21,350,000 tons), 54,000 tons of 80 per cent. ferromanganese could be saved.

The investigation here reported indicated that three practices for utilizing our domestic alloys in open-hearth steel practice seem to commend themselves above the others. These are as follows (but not in the order of their importance): 1. The use of a "molten spiegel mixture" for deoxidation and recarburization. 2. The practice of melting and refining the steel bath so as to insure a comparatively high residual manganese content, say 0.3 per cent. Mn. 3. The use of manganese alloys containing silicon. In selecting plants for investigating these practices, two points were kept in mind. The plant should have either "ordinary" practice, for the sake of comparison, or else one of the three just mentioned, and the product or kind of steel made should be representative of the larger tonnages such as shell steel, plates, or sections.

"MOLTEN SPIEGEL MIXTURE" PRACTICE.

The practice has been adopted at a few plants of combining in one operation both recarburization and deoxidation by using a mixture of pig iron and spiegel that has been premelted in a cupola. This "molten spiegel mixture" contains 5 to 11 per cent. Mn, 4 per cent. C, and the desired amount of Si, and is added to the ladle during the tapping time in such a way as to cause a thorough and uniform mixture of the two streams.

The principal advantages of interest here, not considering questions of plant and operating economy, are as follows: 1. A low-grade or domestic alloy can be used in the preparation of the "mixture." 2. The deoxidation is accomplished by means of a dilute solution with a consequent increase (on theoretical grounds) of the efficiency of the deoxidizer. This point will receive further consideration. 3. The deoxidizer is added in the molten state, insuring certain attendant advantages, which will also be considered at greater length. 4. A special advantage, if a large steel output is desired, is that the amount of the recarburizer is comparatively large and the capacity of the plant is materially (and economically) increased thereby. There is some question as to the propriety of including this advantage as peculiar to this particular practice. The use of pig iron as a recarburizer may be accomplished in other ways with the same economy and increase in plant capacity. 5. Another advantage would seem to the writer to be as follows: As compared with the results in the usual practice of adding carbon and manganese, there should be less likelihood of missing a heat.

This practice, at least at the plant visited, and it is understood to be the same elsewhere, is limited to the manufacture of the high-carbon steels or those running 0.30 per rent. or more of carbon. To make steels

[1]Ellicott, C. R. Manganese conservation in steel making, *Iron Age*, vol. 101, June 6, 1918, pp. 1484-1485.

with 0.20 per cent. carbon would require the working of the carbon until the content was about 0.10 per cent., and the molten mixture added would have to contain about 20 per cent. manganese (spiegel). The amount of the addition would be reduced from 13,000 pounds to about 4,000 pounds, which would mean that some of the advantages just enumerated would be lessened, and, with the increased loss of manganese the practice would probably not be commercially feasible. On second thought, however, when the other alternative, the use of ferromanganese, either solid or liquids is considered, the practice of premelting spiegel in the cupola would seem to commend itself, on grounds to be considered later. In case of undue shortage of high-grade ferromanganese there can be no doubt that the practice would offer a ready solution of the problem of using domestic alloys in making steel for shapes, plates, etc. Against the increased cost of production, as compared with the cost of cold ferromanganese practice, there would be greater uniformity of product and more uniform practice as an offset.

HIGH RESIDUAL MANGANESE PRACTICE.

At certain plants the practice of preferential oxidation and elimination of carbon and phosphorus has been developed, the residual manganese being kept at a comparatively high value, say, 0.25 to 0.30 per cent., as compared with 0.10 per cent. manganese for a final carbon content of 0.10 per cent. This is accomplished, broadly speaking (a) by rapidly removing the phosphorus and retaining it as stable calcium phosphate during the earlier and colder period of melting; (b) by maintaining a high finishing temperature and working the charge with a high manganese content so that the slag contains about 8 per cent. manganese; and (c) by increasing the lime content of the slag to about 47 per cent. as a minimum.

This process possesses undoubted advantages but they are such that they are probably best appreciated by plants in which it has been developed and where it is now in operation on a sound commercial basis. First of all it may be stated that the practice, correctly applied, leads to the production of high-grade and uniform steel, which in itself means increased rolling-mill output, fewer rejections, and a more ready market. This is largely due to the fact that the steel is made —where it should be made—in the furnace.

A second advantage derived from the high MnO and CaO contents of the slag, is that the manganese finals can be added to the furnace with a recovery comparing favorably with that of ladle additions. A third advantage is that the same pig iron used for the charge, and containing appreciably more manganese than ordinary basic iron does, can be used to recarburize and partly deoxidize the bath. The remainder of the manganese is added as ferromanganese. At a steel plant which operates in conjunction with a blast-furnace plant, a harmonious and economical cycle of plant operations is made possible. At the same time the open-hearth slag can be resmelted in the blast furnace for the recovery of the iron and manganese and the utilization of the lime.

This line of practice is largely dependent upon the amount of phosphorus in the slag, for, obviously, it would not be worth while to recover the manganese at the expense of unduly increasing the phosphorus content of the pig iron. In this country we are fortunately situated in this respect, inasmuch as there is still a large amount of rather low phosphorus ore available. No definite figure can be given at this time as to the maximum allowable phosphorus content of the pig iron, but it is the opinion of at least one steel man who uses this process that 0.6 per cent. phosphorus would not be prohibitive. Under the conditions prevailing during the past year, this practice possessed the additional advantages that the high-manganese pig iron could be procured by smelting domestic manganiferous iron ore and that the manganese alloy added to the furnace at the end of the heat could as well be spiegel as ferromanganese, assuming that the finished steel contains more than about 0.10 per cent. carbon. There would also be certain disadvantages, particularly that the carbon content of the bath would have to be worked to a lower figure than in present practice. On account of the high cost of spiegel and the greater time required, it is doubtful whether the steel plants would substitute spiegel for ferromanganese. Another interesting point, in connection with the possibility of utilizing domestic manganiferous iron ore, is that low-silica ore could be added to the slag as a source of manganese oxide.

The high manganese content of the charge is generally obtained by using a "high-manganese" pig iron, 2 to 3 per cent. manganese, but may also be obtained by adding manganese ore to the slag, or manganese alloys to the bath, or by a combination of these methods. This point would be determined by plant economy but it seems doubtful whether the practice would be worth while unless a high-manganese pig iron were available. The writer is informed by one blast-furnace superintendent that running the manganese up to 2 per cent. does not materially affect the production, so that lowering of pig iron production would not be held as a disadvantage in this practice. The loss of manganese by oxidation and transference to the slag is considerable. This loss may be kept at a minimum by increasing the basicity of the slag in CaO and FeO, which, combined with the MnO which also acts as a base, exert the desired effect upon the manganese of the bath.

As the working of the charge progresses, its temperature rises until finally with the high CaC, and, particularly the high MnO content of the slag, the carbon is eliminated more rapidly than the manganese, with the result already stated, namely, the manganese can be held to about 0.3 per cent. at the end of the heat. Present data indicate, unfortunately, that no material increase in the recovery of manganese in the additions may be expected, so that the advantages are derived not from a decreased consumption but from the form in which it can be added.

Data for one such heat showed that a total of 3,728 pounds of manganese was used in one form or another to produce 1,272 pounds of manganese in the finished steel, or, in other words, that 3.54 pounds of manganese was used to produce 1 pound of manganese in the finished steel. The manganese added in the recarburizer and as ferromanganese amounted to 1,068 pounds of which, assuming the manganese loss to come from these two sources, 838 pounds was recovered in the finished steel, a recovery of 78.4 per cent. In this heat the ferromanganese was added to the furnace. Another more or less comparable heat selected at random, but more representative of "standard" practice, used 2,190 pounds of manganese to produce 1,200 pounds of manganese or 1.82 pounds of manganese (as compared to 3.54 pounds to produce 1 pound of manganese in the finished steel).

USE OF MANGANESE-SILICON ALLOYS.

The high silica content of most of our domestic manganese and manganiferous iron ores made it advisable to consider the possible use of manganese-silicon alloys in steel making, in both acid and basic practice. For the purposes of the present discussion, these alloys will be divided roughly into two classes—high-grade silico-manganese containing about 50 per cent. Mn and 25 per cent Si, and low-grade silico-spiegel with about 15 to 20 per cent. Si and 30 to 35 per cent. Mn with 50 per cent. Fe. The manganese-silicon ratio of the first alloy is about 2 and of the second alloy 2 1/3 to 1½. Each of these alloys would be made from the silicious manganese ores of California and Montana, and the low-grade alloys from the silicious manganiferous iron ores of Minnesota.

While there is nothing new about the practice of using manganese-silicon alloys in steel making, it may be well to review some of the points connected therewith in the light of present requirements.

Silicon is always an efficient reducing or settling agent when used in the customary small amounts. It is understood that "silicomanganese" has been used fairly extensively in Europe, and in this country it was used at certain plants as standard practice until the supply was cut off by the war. Silicon is always an efficient reducing or settling agent when used in the customary small amounts, but it may or may not be desirable in the finished steel. On this account, the possibility of using manganese-silicon alloys depends upon the amount of silicon that can be tolerated in the finished steel in the ingot form. In certain grades of steel, particularly in steel that must be welded, silicon should be low or practically absent. In steel for sheets and plates, which must give a good finished surface, the most efficient rolling-mill practice requires that the silicon be kept tolerably low, but it is believed that 0.10 to 0.15 per cent. could be used, provided the manganese content were not too high. In forging steel, high-carbon steels, and castings, where the aim is to produce sound steel, more silicon can be used, or between 0.20 and 0.35 per cent. Of these three fields, the latter is the one in which manganese-silicon alloys will find their first application. In the second field, it seems quite probable that conditions (to be discussed later) will many times permit their use; but from the very nature of things manganese-silicon alloys cannot be used to make steels of the first group—those that must be welded.

MANGANESE-SILICON ALLOYS IN ACID PRACTICE.

It is with considerable hesitation that the discussion of manganese-silicon alloys in open-hearth practice is approached, particularly as the controversial character of many of the points is so clearly recognized. Consequently, it may be well, at the outset, to state briefly the manner in which the writer first became interested in the possibilities of their use. A number of years ago the writer was conducting a series of experiments on the occurrence and identification of foreign inclusions in acid open-hearth steel, principally ordnance steel. In this work ferromanganese, ferrosilicon, and a mixture of ferromanganese and ferrosilicon were added to a steel sample taken shortly after "oreing," that is, to "wild" steel, in an attempt to produce an excess of the constituent, or constituents, supposed to form as a result of the addition.

It seemed fairly clear as a result of this work that the use of silicon was apt to be dangerous, not on account of any harmful effect of the residual metallic silicon but because it produced a constituent (assumed to be SiO_2 or at least a highly refractory silicate) that was likely to remain in the ingot and produce hot shortness. Hence the idea was suggested that a manganese-silicon alloy might and probably would, form a manganese silicate containing some ferrous oxide (a true slag) which would be fluid and more readily coalesce into larger particles than SiO_2 would, and therefore free itself more readily from the steel. By using such an alloy it would then be possible to take full advantage of the use of silicon as a deoxidizer without suffering the usual attendant disadvantages of its use. None of the manganese-silicon alloy was available at the time so a parallel experiment could not be conducted.

As binary alloys are known to be generally more active, or powerful, than the weighted sum of the two constituents would indicate, it was also assumed that, aside from the possibility of obtaining a better separation of the insoluble products of the deoxidation process, the alloy of manganese and silicon would prove to be a more powerful reducing agent than ferromanganese and ferrosilicon used separately. On reflection, the thought occurs that manganese and silicon, reacting separately with FeO, would produce the oxides MnO and FeO or a silicate of iron. Manganese and silicon reacting as an alloy with FeO would produce a silicate of manganese, which may or may not form a double silicate with FeO. In either case we would expect to find the advantage in favor of the manganese-silicon alloy.

The relative weights of the silico-manganese and of the mixture of the ferromanganese and ferroscilicon will be considered at another place.

Another point of great technical importance is the percentage recovery of manganese when added as silicomanganese and as ferromanganese along with ferrosilicon. First of all let it be stated that a 100 per cent. recovery, based on the present theory of "deoxidation," is hardly possible, and if possible would not be desirable. Such recovery would mean a retention of the products of the deoxidation, to be determined later as metallic manganese and silicon. A method of addition that would lead to a satisfactory deoxidation and yet would eliminate the loss due to admixture with the slag, volatilization, etc., and could be accomplished with the minimum amount of manganese, would be very desirable because it would lead to both conservation of manganese and uniformity of composition of the steel. Conservation of manganese would be given by the actual value of the percentage recovery of the manganese, and uniformity of composition would be assumed by the constancy of the percentage recovery.

Fortunately the writer was able to examine records of heats made with silicomanganese covering a period of several years, from which some fairly satisfactory conclusions may be drawn bearing on these points. During this time when silico-manganese was being used there were periods when the alloy was not available and the mixture of ferromanganese and ferrosilicon had to be substituted. Thus, a direct comparison of these two methods of deoxidation was afforded.

It can hardly be claimed for the figures obtained, or for the three years' records which they represent with reasonable accuracy, that they furnish a truly scientific basis of comparison of the two alternate practices, but they do show rather convincingly that the same results (Mn and Si contents of the finished steel), by using silico-manganese can be obtained with consistently smaller amounts of both manganese and silicon, as compared with the combination of ferromanganese and ferrosilicon. In addition there is the advantage of having a more uniform practice, which in itself would warrant smaller additions. The weights of the additions favor the silicomanganese in some cases by as much as 460 pounds against 385 pounds and 615 pounds against 510 pounds. The low carbon content of the silicomanganese may or may not be a material advantage but at any rate it is in favor of the single-alloy addition because the carbon need not be worked as low and there seems to be less danger of missing the carbon.

Pouring nitroglycerine into a shell to be exploded at the bottom of an oil well to stimulate the flow of oil

Train of tank cars being filled at an oil-loading rack in the Oklahoma oil fields

Our Liquid Fuel

Methods and Magnitude of Petroleum Production in the United States

DOUBTLESS a good many folk who have never seen an oil well do not properly visualize the amount of labor—skilled labor—involved in bringing the liquid fuel to the surface. We are apt to think of an oil well as a hole in the ground which yields oil without let or hindrance, and especially without any very great effort on the part of its fortunate owners. The accompanying photographs, taken in the Texas-Oklahoma oil fields, may relieve this misunderstanding.

The bare process of getting the oil out of the ground is not, after all, so very complicated. To be sure, until recent years there was a good deal of hard work and even more of chance in the capping of a gusher; and the owner of a new bore that is inclined to be really violent will bless the name of the man who can show him how to save a maximum of the fluid that it gives forth before it is under control. And on the other end of the scale, we have scope for some expert aid to the well that seems about to end its active career. The nitroglycerine cartridge which we show being filled preparatory to lowering into the bottom of the drill and discharge there, will, if it is successful in its mission, blow out the walls between adjoining oil pockets and add the contents of the surrounding chambers to the dwindling supply available for delivery to the surface from the one originally tapped by the bore.

But the real work of the oil producers comes after they get the oil in their hands. The crude oil is seldom shipped; there is no particular point in buying space for it, when it can just as well be distilled into its fractions right on the spot, and these marketed with a minimum of freight bills. So we have located right in the oil fields big batteries of stills and condensers like the one illustrated, which converts into gasoline, kerosene, and other less familiar substances the petroleum from a series of wells near Cushing, Oklahoma.

Another picture which gives some idea of the magnitude of this end of the oil-producing game is the exterior view of a similar plant at West Tulsa. Equally illuminating is the scale upon which shipments are made. We show a train of tank cars being loaded from the big tanks near Cushing, the metropolis of a considerable oil district. So much oil is produced in this region, in fact, that the owners of the wells have constructed an 800-mile pipe line from the fields to Chicago, relieving the railroads of the handling of some 20,000 barrels of oil per day, and incidentally relieving the oil in large measure of the weight of this transportation charge.

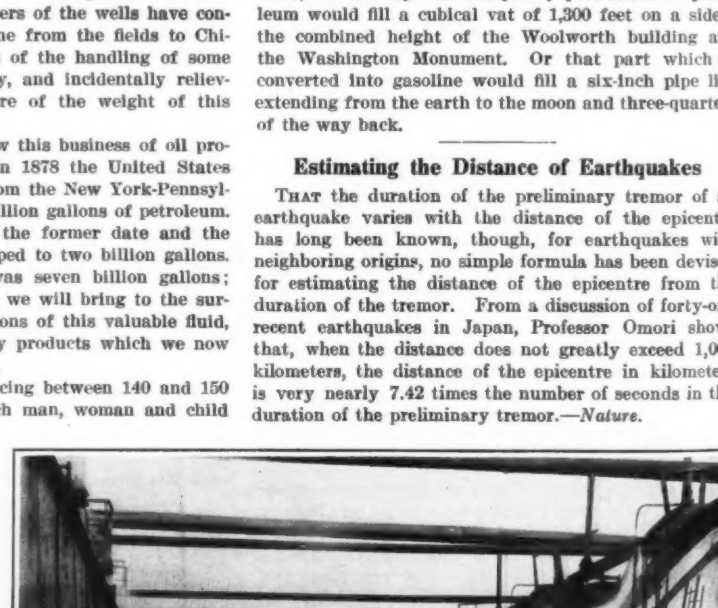
It is interesting to see how this business of oil production has grown. Back in 1878 the United States extracted, almost entirely from the New York-Pennsylvania-Ohio field, some 650 million gallons of petroleum. In 1898, half way between the former date and the present, production had jumped to two billion gallons. Ten years ago the figure was seven billion gallons; and for 1919 it appears that we will bring to the surface some fifteen billion gallons of this valuable fluid, for conversion into the many products which we now know how to make from it.

At this rate we are producing between 140 and 150 gallons of petroleum for each man, woman and child in the country. From this, there will be refined perhaps 32 gallons of gasoline and 17 of kerosene per capita—estimates for these two products running in the neighborhood of 3,300,000,000 and 1,700,000,000 gallons, respectively. Putting it on another basis, if each of our automobiles consumes, as ordinarily supposed, 500 gallons of gasoline per year, the 3,500,000 cars in the country will use half of the gasoline manufactured, leaving the rest for the farmer and the aviator and anyone else who may have a claim to a share in it.

If we are asked to put the matter on a graphical basis, we can say that the yearly production of petroleum would fill a cubical vat of 1,300 feet on a side—the combined height of the Woolworth building and the Washington Monument. Or that part which is converted into gasoline would fill a six-inch pipe line extending from the earth to the moon and three-quarters of the way back.

Estimating the Distance of Earthquakes

THAT the duration of the preliminary tremor of an earthquake varies with the distance of the epicentre has long been known, though, for earthquakes with neighboring origins, no simple formula has been devised for estimating the distance of the epicentre from the duration of the tremor. From a discussion of forty-one recent earthquakes in Japan, Professor Omori shows that, when the distance does not greatly exceed 1,000 kilometers, the distance of the epicentre in kilometers is very nearly 7.42 times the number of seconds in the duration of the preliminary tremor.—*Nature.*



Exterior and interior views of big distilling and condensing plants in the oil regions of Oklahoma

Animal and Vegetable Rennets*

Their Properties, Their Preparation, and Their Mode of Action

The coagulation of the casein of milk by rennet is one of the most singular problems in biological chemistry, and still imperfectly understood, though much studied by such men as Richard Peters, Duclaux, Chodat, Javillier, Gerber, etc.

Animal Rennet.—Rennet is secreted by the gastric glands of young animals; it also appears in the stomach of adults when milk is taken. Rennet solidifies the casein into an unctuous mass very different from the crumbly mass produced by acids. Its active principle is an enzyme, *chymosine* or *lab*, always found mixed in the stomach with two other ferments, pepsin and trypsin or casease, whose function is the digestion of milk. Rennet is used in cheese making.

Common butterwort, and its flower

Cleaning the Rennets.—The rennet bags of calves, lambs or kids are prepared in abattoirs or even by gut workers. They are scraped to remove the clotted milk, tied by a string at one end, inflated with air and dried. After a few days they are deinflated, packed in dozens and sent to the factories.

Industrial Preparation. — The rennets, cut in thin strips, are macerated in salt water at 35° C., 50 gr. of salt and 60 gr. of rennet to a little of water; after five days they are carefully filtered. The liquid thus obtained is the usual rennet, whose coagulating power =10,000. Most manufacturers add 4 per cent. of boric acid to preserve it; others get the same result with a little glycerine or alcohol; some, finally, fraudulently add hydrochloric acid, which increases the coagulating power but gives a curd which is hard to work. By evaporating the liquid rennet, or precipitating it with alcohol, solid rennet is procured and sold in cakes whose coagulating power is 30 to 40 times as great as that of the liquid for an equal weight.

Determination of Coagulating Power. — Rennets offered in the market are stamped with a mark showing their degree of coagulating power. *Normal* rennet is that one volume of which ensures the total coagulation in 40 minutes of 10,000 vol. of milk kept in the water bath at a temperature of 35° C., or otherwise that one volume of which in the same conditions of temperature ensures the total coagulation of 10,000 vol. of milk in 4 minutes (240 seconds).

If a specimen of rennet, held at 35° C., coagulates 10,000 times its volume of milk in 160 seconds its coagulating power is equal to

$$\frac{240}{160} \times 10{,}000 = 15{,}000$$

In practice the operation is as follows: One cubic centimeter of the rennet to be tested, diluted with 10 times as much distilled water, is poured into 100 cc. of milk kept at 35° C.; the time required for complete coagulation is then noted. The power is obtained by multiplying 10,000 by a fraction whose numerator is 240 and whose denominator is the number of seconds required for complete coagulation.

Properties of Animal Rennet. — There are certainly slight differences in the composition of rennets coming from different species, which explains, for example, why sheep's milk is not coagulated well except by lamb's rennet; but these are so unimportant as to be negligible.

Animal rennet coagulates *raw* milk readily and *boiled* milk with difficulty. It acts only between 20° C. and 60° C., the optimum temperature being 40.5° C., *i. e.* the one which acts most rapidly. The coagulation is accelerated by acids, by the neutral salts of calcium and of barium, and is retarded by the bases and neutral salts of potassium and of sodium, and by dilution with distilled water. The coagulation of the casein is always total, whatever the percentage of rennet used, but the time required is longer in proportion as the percentage is less and as the temperature is lower. This is expressed in the law of Segelcke-Stork: The product of the mass of the ferment by the time required for the total coagulation of the milk operated upon by rennet is a constant number.

White cheeses, for immediate consumption, are obtained from milk held at a low temperature (18° C. to 20° C.) and with an amount of rennet calculated to produce complete coagulation in 20 to 24 hours; the curd thus formed becomes very unctuous. The cheeses fermented in a state of *soft paste* (Brie, Camembert) require a coagulation period of one to three hours, the temperature of the milk varying from 28° C. to 32° C. The *hard paste* cheeses (Dutch, Parmesan) require a rapid coagulation (15 to 60 min.), the temperature of the milk varying from 34° C. to 40° C.

Vegetable Rennets.—The researches of Gerber have shown that almost all plants contain a juice having the properties of rennet and which is specially abundant in the green organs (young stalks, buds, leaves), in the flower (especially the style), the young fruits and the seeds. The following may be noted as particularly rich in rennet: the wild or prickly artichoke, the yellow cheese-rennet, the common fig, the butterwort, the papaw, the *witania coagulans* of India, the paper mulberry, the darnil, the lucerne, the lupine, the euphobias, the madder, etc.

Properties of Vegetable Rennets. — Many of their properties are identical with those of the animal rennets, but they act chiefly at high temperatures. The optimum temperature is about 75° C.; it may go as high as 80° C. for the papaw rennet, 85° C. for that of the pastel or wood, and even 90° C. for that of the fig. These rennets act hardly at all on milk below 20° C.; however, that of the papaw will coagulate milk even at 0° C. (32° F., or freezing point).

The coagulation is always accelerated by increasing the percentage of rennet, by raising the temperature (up to the optimum peculiar to each species), or by increasing the percentage of mineral or of acid content. Bases retard or prevent the action of vegetable rennets.

According to Gerber these ferments may be divided into 2 classes: 1. The rennets of *boiled* milk, the most numerous, which coagulate boiled milk more readily than raw milk (fig, pastel or wood, etc.); 2. The rennets of raw milk, which have the inverse property; such are the wild artichoke and the paper mulberry.

Wild or Prickly Artichoke (a) flower, (b) fruit

True cheese-rennet, with flower enlarged

Preparation of Vegetable Rennets.—There are several processes for extracting the rennet forming juices of plants. The method of Javillier furnishes juices exempt from microbes; the plant is crushed and the juice pressed out; the extracted juice is then saturated with chloroform, placed in a full flask and stoppered and kept in a dark place for 24 hours; it is then filtered through filtered paper, neutralized by soda, and sterilized by filtering through a porous flask.

Chodat's method, which is simpler, consists in macerating for from 24 to 48 hours the active parts of the plants cut into small fragments in salt water (à 7% solution) to which have been added a few drops of the essential oil of mustard. Finally, one may confine himself to precipitating the juice of the rennet forming plants by alcohol. In practice it is the fresh plants alone that are employed. Hence their utilization is possible for a few months only each year: in the spring in the case of the rennet forming buds; in the summer with the flowers, etc. Herein lies an inferiority to the animal rennets.

Method of Employing Vegetable Rennets.—These ferments have been used from the most remote times to prepare curds of milk and cheeses. Homer speaks of them in the Iliad.

In the west and the middle of France it is customary to use flowers of the wild artichoke (*cynara carduncului*), which looks like a large thistle, attaining a height of more than a meter. Two or three stalks of this plant, which usually grows in uncultivated places, are often raised in gardens for the purpose of making compressed curd or cottage cheese. A pinch of the flowers tied in a little muslin bag is placed in the heated mill; at a temperature of about 65° C. coagulation is very rapid.

The true cheese rennet (*galium verum*) is one of the madder tribe and is very common in our meadows. This perennial herb, half a meter tall, has leaves in whorls of 6 to 12. Its flowers are small and numerous, of a clear yellow and with the odor of honey; they appear from June to September. In the west of England the flower heads are employed for the preparation of cottage cheese. Mixed with calf rennet they are used in making Chester cheese, to which, moreover, they impart a yellow color.

In the Balearic Isles the peasants, who are very fond of clotted milk, prepare it as follows: The milk is boiled, and while still very hot it is stirred with the young branch of a fig tree, left crosswise. Almost at once the milk forms a homogeneous mass which is immediately eaten with a spoon. The fresh fig branches may be replaced by a rennet-forming solution procured by macerating young roots in salt water. This solution acts rapidly upon raw as well as upon boiled milk, at about 70° C.

In Lapland and in the villages of the Italian Alps the curd is prepared with the leaves of the common butterwort (*pinguicula vulgaris*). This little perennial herb dwells in the peat lands and the humid places of the extreme North and of mountainous regions. In the center of its foliage rosettes rise in May and August, its flower stalks of a height of 8 to 15 cm. The flower, provided with a spur is blue, violet, rose-pink or white.

In Japan the leaves of a very widely grown tree, the paper mulberry, are used (*broussonetia papyrifera*); in the warm regions the juice of the papaw (*carica papaya*), etc.

The seeds of the *punceria* or *witania coagulans*, one of the *solaneae* of India, are very rich in rennet. When macerated in salt water to which 4% of alcohol has been added they yield a solution which keeps well and whose activity almost equals that of animal rennet.—F. Faidean, in *Larousse Mensuel* (Paris).

The Threshold of Vision

A note on recent determinations of the minimum light perceptible to the human eye was given in *Science Progress*, 12, 552, 1918. The direct determination by Reeves was based upon observations of an artificial star 1 mm. in diameter from a distance of 3 meters. In *Astroph. Journ.*, 47, 141, 1918, he gives the results of further investigations as to the effect of the size of the stimulus and the time of exposure on the retinal threshold. The absolute threshold was determined for stimuli varying in size from a 2 mm. square to a 12 cm. square and viewed at various distances. In each case, before taking an observation, the eye was adapted to darkness. It was found that the threshold decreased considerably with increase in the size of the stimulus, but that the total energy entering the eye showed an increase.

Attempts were made to determine the length of time required for a point source to produce a perceptible sensation. For just perceptible intensity, the time was found to average about 2 secs. Independent experiments were made with calibrated photographic shutters placed before the test spot and the brightness necessary for the test spot to be perceived when exposed was determined.

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Animal Luminescence and Symbiotic Microbes*

New Light Upon the Much-Debated Question of Pasteur's Beneficent Organisms

By Prof. Umberto Pierantoni of the University ot Naples

EVER since Pasteur published the results of his remarkable researches concerning the part played by micro-organisms in the phenomena of fermentation and in producing pathological effects, and especially since the studies of other investigators have thrown light upon the multiform activities of these microscopic creatures, interest has been felt in the question as to whether it is possible for these activities to be utilized in certain cases by the higher organisms concerned to promote their own welfare. In other words, do there exist not only pathogenic germs but beneficent or "physiologic" germs, *i. e.* germs which assist the operation of the normal life processes in the higher animals.

We have no space here to enumerate all the attempts made to support by concrete facts this alluring hypothesis, which is so well capable if it be correct of explaining many of the highly complex phenomena of cellular metabolism. It would be a futile task, furthermore, since none of these theories has been finally accepted. . . . There is, however, a certain relationship between these doctrines and a conception of the existence of elementary living particles which constitute histologic individuals of a lower order, which possess a life of their own and which by their union form superior elements and thus determine the various activities of the cellular plasmas. We may recall in passing the micellae of Naegeli, the bioblasts of Altmann, the biophores of Weissmann, microsomes, plastidules (Maggi, Elsberg, Haeckel), the vacuolids of Dubois and other formations which are, perhaps, sometimes more imaginary than real; the object of each of these hypotheses is the endeavor to explain the existence and the method of functioning of plasmas, an object in which most of them are not very successful.

Most of these theories, however, have no resemblance to the conception of physiologic micro-organisms. They remove the problem, on the contrary, to a class of facts which are difficult to prove because they probably lie entirely outside the normal methods of observation and the technique involved in the strictly experimental study of those cultures which we have at our disposal. We must seek for facts capable of supporting the theory of the existence of physiological microbes in what we know with regard to the life of those micro-organisms with which we are familiar, *i. e.* the lower species of fungi (Blastomycetes, schyzomycetes). But it is none the less true that so long as we are obliged to content ourselves in this investigation with data which have been known for the last four or five years, we must admit as regards the bacteria as well as the blastomycetes, that the only forms known are the saprophytes (agents of fermentation) and the parasites (pathogenic germs). This is the general conclusion with regard to this problem found in all modern treatises and it is the general opinion of authorities upon the subject that living and healthy tissues must be considered to be absolutely aseptic.

If we turn to plants, however, before considering the tissues of animals, we find a number of bacteria which might possibly be regarded as beneficent, or *physiologic*, to use the term we prefer. Such, for example, are the tubercles of orchids and the root tubercles of the leguminous plants; the latter are raised by the plants for the purpose of fixing the nitrogen of the air and enabling the soil and the plants which grow therein to make use of it, as they are not able to do while it remains an inert substance floating in the atmosphere. The usefulness of these microbes is now undisputed, and the same thing is true of the analogous micro-organisms which live in the soil in a free state and which contribute so largely to the welfare of the plants which live in the same territory.

But are these really physiologic bacteria in the true sense of the word? It must be granted that they are of great physiologic importance in the world of plants and likewise in the domain of practical agriculture. But they do not come outside the head, precisely speaking, of those we have here in mind, since these bacteria are utilized to accomplish the execution of a function which inheres, not in the individual plant to which they are attached, but rather in a community made up of individuals belonging to the species which harbors these bacteria and of individuals of various other species as well.

Returning to the animal kingdom we may cite certain cases which have long been pointed out as examples of beneficent microbes. Thus the investigations of Pasteur proved the presence of certain kinds of bacteria in the alimentary canal of man and of other animals. These organisms, which doubtless are taken into this digestive tract with food or drink find therein favorable conditions of existence and proceed to multiply. But they are rather *commensals*, *i. e.* table companions, than parasites of their host. Some of these bacteria, it is true, exert a favorable influence upon the process of digestion, stimulating it by their diastases. The digestion of certain substances, cellulose among others, may be due to these micro-organisms, which effect a bacterial digestion which accompanies the ordinary digestion.

This alluring theory is much disputed even yet, in spite of its apparent truth, and Pasteur's assertion that nutrition, and consequently life itself, would be impossible without the intervention of bacteria is still generally considered as exaggerated to say the least. Furthermore, the digestive power of the diastases is here exhibited, not within the cells of a secretory organ, but freely, within an intestinal cavity, *i. e.* in a cavity communicating with the exterior; hence the theory of the aseptic character of the tissues remains unaltered, even though the digestive power of the intestinal bacteria be irrefutably established.

* * *

The first instance which strictly concerns the concept of the existence of micro-organisms which determine the functioning of an organ was the subject of a personal investigation by myself, and has been described in a series of monographs whose publication began in 1910. These researches had as their point of departure the fact that this sort of physiologic symbiosis is not confined merely to one or two species, but is encountered in a whole suborder of insects which comprises several hundred, and perhaps several thousand species—in the homopterous hemiptera, *i. e.* in all those insects which live upon the juices of plants, and which spend the greater part of their lives with their probosces penetrating the leaves and stalks of plants in order to extract nutriment therefrom (the aphid, the cochineal, the cicada, the psylla, the aprophore, etc.)

It is a fact well known, even in what is called "popular science," that many of these creatures, and more especially the aphids or plant lice, the cochineals and the cicadas are species which produce sugar, which they extract from plants, either in an already elaborated state or in the form of starch, in such large quantities that they are not capable of digesting all of it as it passes through the intestine, but are obliged to excrete a part of it unaltered. It is a matter of popular knowledge, too, that ants rear aphids as men rear herds of cattle in order to obtain this sugary juice of which they are exceedingly fond, as also that ants "milk" the cochineal to obtain these sweet juices and form actual processions on the trunk and limbs of infected trees.

But my personal researches, referred to above, have proved that all these juice-sucking and sugar-execreting insects possess clearly perceptible organs situated within the cavity of the body which are composed of a mass of cells filled with blastomycetes which live and reproduce themselves therein, and there exercise their normal activity, which consists in decomposing the sugar into alcohol and carbon anhydride, the former being utilized by the organism, while the latter is emitted through the tracheae with which the organs in question are very abundantly supplied.

It is evident that in this case the work of these symbiotic organs is accomplished solely and entirely by the labor of the intracellular micro-organisms. It can be no affair of a simple and temporary adaptation of these microbes to the intracellular life, for the fact is absolutely general in character, *i. e.* characteristic of every individual of every species, and since the constant presence of these microbes is assured by the circumstance that they are transmitted by heredity from generation to generation. In other words they pass from the symbiotic organs into the egg, where they constitute a group at one end which becomes surrounded, as the embryo develops, by the initial cells of the organ which in the adult will derive its functional activity from these very microbes, which will in this latter stage have become very numerous.

The mycetologic researches which followed upon the publication of my observations in this field have established the fact that the various species of homopterous insects harbor various species of symbiotic microbes. One can readily imagine therefore the incalculable number of mycetological species which remain to be studied with reference to their morphological peculiarities, their manner of existence, and their vital activity. And there is nothing to forbid the possibilty that some of these species may be found to be practically useful in industry or in therapeutics. Those species of blastomycetes which produce fermentation have long been familiar to man and are utilized in both medicine and the arts and industries, even though not adapted to life in the interior of the organism. It is not a bizarre idea therefore to hope that our researches along the present line may lead to the eventual discovery of a species which will be of practical utility. Indeed we consider this as very probable.

The phenomenon I have described is certainly far more widespread than would at first appear. The French physiologist Portier has within the last few years demonstrated the existence of symbiotic microbes in the adipose substances of the xylophagic or wood-eating insects. According to this authority these microbes render possible the digestion of the wood which forms the food of these insects. Symbiotic micro-organisms, especially bacteria, have been found living within nearly all insects and also in healthy tissues of other animals; an apparent organ which is found in the cephalopods (cuttle fish, etc.), and which is known by the name of the accessory nidamental gland because it is believed that its secretions contribute to the formation of the shell and the envelops of the egg, is also a symbiotic organ as shown in some of my own recent researches, being packed with bacteria of different species whose activity still remains to be studied; it seems to be connected with phosphorescence in those species which like the cuttle fish do not posess luminous organs. These bacterial forms of the accessory gland, which are sometimes intracellular and sometimes enclosed in the cavity of the glandular tubes, according to the age of the animal which serves as host, are also transmitted by heredity in the egg from generation to generation. When we consider the number of cephalopods which possess this gland it becomes clear to mycetologists that there are probably hundreds of useful bacterial species.

Thus the dogma that sound and healthy tissues are necessarily aseptic is daily undergoing attack, and a vast field of research is opened with regard to the assistance which may be rendered by all these symbiotic microbes in the activities of the various organs.

* * *

A series of observations recently made by me at the Zoological Station of Naples the results of which are in course of publication, opens new and vast horizons to researches concerned with newly discovered facts which are closely connected with the phenomenon of physiologic symbiosis. The observations in question furnish irrefutable proof that many luminous animals inhabiting the depths of the sea produce their characteristic phosphorescence by utilizing as sources of luminosity actual "cultures" of photogenic bacteria which they harbor in special organs provided with special devices which are designed to render the luminosity of the bacteria more intense; these devices include lenses, reflectors, and pigmented zones. Furthermore, these bacteria which are in an active state of reproduction in the organs which harbor them and are therefore constantly increasing in numbers, are capable of being projected outwards at the will of the animal which acts as host, in the form of a very beautiful little "cloud of light," so to speak, which lights up the surrounding water.

Thus these cephalopods, which comprise several species belonging to different genera (*Sepiola, Rondeletia, Heteroteuthis Emprymna*, etc.) have at their disposal two different apparatuses which function in contrary manner: the "ink" gland, whose secretion avails to obscure the water, thus permitting the animal to escape from its enemies; and the luminous organ, which illuminates the surrounding waters when the animal is at rest and which is likewise capable of rendering the water itself luminous by means of a mechanism which resembles that of the "ink" gland. We have here a curious contrast of functions which is perhaps explained by the fact that these animals are capable of living not only in shallow waters penetrated by the light of the sun, but also in dark abysms several hundred meters deep.

It is easy to prove the bacterial nature of the lumi-

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nous substance of the photogenic organs of these cephalopods, since in suitable mediums of culture (cuttle fish bouillon and peptonized agar-agar dissolved in cuttle fish bouillon) we are able to obtain very beautiful phosphorescent colonies; these in the opinion of skilled bacteriologists who have made a study of them, seem always to consist of two kinds of microbes having forms and properties which are identical with those of the corpuscles of the luminous substance which is extracted directly from the organ. These cultures, whose luminosity persists for several weeks, are so intensely phosphorescent that it is possible to take photographs by these means with comparatively short exposures.

These studies indicate therefore that a heretofore unsuspected importance attaches to these photogenic bacteria with respect to the phenomena of the phosphorescence of the sea and of the inhabitants of its depths; and the existence in the abyss of the sea of animals capable of emitting luminous clouds of bacteria gives probability to the theory that among the animals which reside in the eternal night of these abysmal deeps those which lack photogenic organs but are provided with eyes owe the ability to live to a stratum of luminous bacteria held in suspension in the water.

While it seems probable that instances of bacterial luminescence in marine animals will be discovered in large numbers in future researches (it seems quite certain already that the brilliant light of the pyrosomes is also of micro-organic nature) I do not pretend to assert that there may not be luminescence of a different sort among the great variety of luminous marine animals, and the same thing may be said of terrestrial animals, among which, however, I demonstrated, in 1914, the existence of bacteria in the luminous organs (*Lampyris* or glowworm).

If we succeed in generalizing the idea of bacterial luminosity many theories which attempt to explain the phenomenon of luminescence upon the principle of the transformation of energy by means of cellular plasmas must be abandoned. In the same way the chemical theories which endeavor to account for luminous phenomena will retain their value only in so far as they concern the problem of the method by which the photogenic bacteria produce light.

The science of pathogenic micro-organisms now accepts as a fact the existence of these bacteria which emit light, even in cases where neither the optical means at our disposal nor available cultures reveal them. Much is to be expected from the ultra-microscope, especially after it has been so far perfected as to be adaptable to all sorts of researches. Those viruses which are known as filtering viruses behave like bacterial colonies as regards the greater part of their normal activities, in spite of the fact that as yet no one has been able to perceive them and cultivate their elements. Those substances which are known as soluble ferments possibly bear the same sort of relation to the micro-organisms which produce fermentation. Going a step further there is nothing to prevent us from supposing that the same sort of relationship may exist between the micro-organisms which produce light and the luminescent substances in which, as yet, no micro-organisms have been found. This brings our problem back to the starting point and reduces it in fact to the one first stated, namely, to the question of the existence of elementary particles having a life and activity of their own and constituting plasmas whose functions they determine.

Much remains to be done in the way of research along this line. We are dealing here with new facts and phenomena which demand a new point of view in a great many branches of knowledge and an ample harvest is to be gathered in this field by the zoologist, the botanist, the physiologist, the chemist and possibly also the pathologist.

* * *

The vital activities as they are revealed in the functioning of the different organs are very varied; in the same manner the work which micro-organisms in general are capable of accomplishing is very various. It may be worth while, at this point, to recall some of these other activities which still await thorough investigation.

We frequently find in the animal kingdom organs whose function is the elaboration of coloring matters such as the cochineal insect, the murex (from which the ancients made a purple dye), the aplysid, etc.; we also know several different species of chromogenic bacteria. The idea suggests itself by analogy that in certain cases the latter may be concerned in the functioning of color producing organs just as the luminous bacteria intervene in the functioning of light producing organs. Another very fruitful subject of study is the extent to which bacterial activities may possibly intervene in the innumerable instances in which histolysis occurs with an accompanying reduction or disappearance of certain parts of the organism, especially with reference to the metamorphosis which many animals undergo at certain stages of their existence, as is the case with insects, amphibians, etc.

The cases in which physiologic symbiosis occurs, which we must now regard as fully established, clearly demonstrate the marked tendency which organisms exhibit to utilize the profitable labors of their symbiotic micro-organisms. Proof of the aforesaid marked tendency is furnished by the existence on one hand of harboring organs having a well defined embryonic history and on the other hand of a complex system of auxiliary organs designed to augment the effect produced, as for example the reflectors and the lenses of bacterial luminous organs; further proof is afforded by the fact that the presence of physiologic micro-organisms is generally assured to the species by means of the hereditary transmission of the germs. The so-called bacteroids whose presence in the eggs of insects has been known for more than twenty years and whose true bacterial nature is no longer to be doubted, also furnish proof of the hereditary transmission of physiologic micro-organisms.

But it is a well known fact that modern science finds it an easy matter either to favor or to check the development of these micro-organisms; consequently, the discovery that the latter sometimes act as the agents which produce the normal functions of higher organisms, has given birth to the hope that scientific skill may some day be able to exert a regulating action upon these physiologic microbes, thus creating a new and interesting branch of therapeutics. Indeed studies in this line have already been undertaken in France, where cultures have been obtained of micro-organisms isolated from the healthy tissues of vertebrate animals and have been studied with reference to their peculiar activities.

Such studies naturally demand both time and diligence to produce valuable results. Thousands of experiments must be made in the domains of histology, physiology, bacteriology, and chemistry before we can affirm with certainty the presence of a given micro-organism in the first place, and secondly the nature of its activities, whether *in situ* or in arificial culture. The troubled years through which we are now passing are not adapted to afford to scientists the tranquility of mind and the moral serenity which are required to work effectively at the solutions of problems so difficult. Many of our finest minds have been torn from the laboratories and transported to the field of battle, often never to return. Furthermore, the development of research has been necessarily retarded by the interruption in the exchange of letters and books between States at war which has put obstacles in the way of obtaining a knowledge of the results of research in any given branch made in a foreign country. And this state of affairs is even more injurious in researches which, like those described in the present article, demand a collaboration in several branches of science and which are difficult to pursue even in normal times, because of the excessive degree of a specialization of the present century. This inconvenience is remedied in part by those periodicals of scientific synthesis which enable specialists in different lines to compare results and make use of such data as concern their own studies.

If this excess of specialization, which has brought about notable progress in many lines but has on the other hand hindered progress by its failure to achieve synthetic results, be an effect of the German methods which have penetrated the science of the Latin peoples, as indeed of all others, then let us hope that the war will bring about a desirable change in this respect.

Let us look forward then to the renovation of our studies with the same confidence with which we regard the prospect of the renovation of so many other activities in the reconstruction period. . . .

Fundamental Concept of Physics

FOR some time past a considerable body of mathematicians have been engaged on a careful scrutiny of the concepts and axioms on which rests the whole body of mathematics, and in the *Physical Review* Dr. R. C. Tolman suggests that the time is ripe for a similar investigation in physics. As any branch of science develops, its considerations become more and more deductive, the ideal form of exposition being one in which all the important relations are derived from a small number of independent general principles and all the terms used are defined with the help of a small number of indefinables, which are certain entities not defined in the particular discussion undertaken, but assumed to be matters upon which for the purposes at hand there is general agreement. Dr. Tolman proceeds to discuss the nature of the quantities which occur in the equations of mathematical physics and to consider a set of indefinables for their definition in the hope that he may thereby help in the preparation for that more complete systematisation of mathematical physics which is undoubtedly coming.

Following Bertrand Russell, the author considers *magnitudes* as indefinable *terms* which are capable of entering into the relations of *"greater than"* and *"less than."* Every magnitude bears a peculiar relation to some particular concept such that we say it is the magnitude of that concept; magnitudes are said to be of the same kind when they bear this relation to the same concept. Only magnitudes of the same kind can enter into the relations of greater and less. Thus we can speak of magnitudes of volume and magnitudes of temperature, and we can say that one magnitude of the concept volume is greater or less than another magnitude of volume, but cannot relate it in this way to a magnitude of the concept temperature.

Quantity is a magnitude which has been particularised by the specification of spatial or temporal conditions, so that, for instance, the statement of the temperature in a given beaker at a given time is a quantity. One quantity is greater than another quantity, when the magnitude of the former is greater than the magnitude of the latter. To speak of *equal* magnitudes would be meaningless; but we can speak of equal quantities—they are quantities having the *same* magnitude.

No reasonable ambiguity arises if we place the different kinds of quantities used by physicists in two general classes—those having *extensive* magnitude and those having *intensive* magnitude. The first class contains those quantities which have a certain additive nature so that a given quantity can be regarded as being the sum of a number of smaller quantities of the same kind; the second class contains those which have no such additive nature. Thus volume is typical of quantities of the first class; likewise mass, energy, entropy. We can decide that such quantities have extensive magnitude by the consideration that the simultaneous presence of two systems, each having a definite quantity of the kind in question, gives a larger system with twice the quantity. On the other hand, density, temperature, permeability, inductivity, are quantities having intensive magnitude. For instance, the consideration of two pieces of platinum at 100° C. gives a larger piece of platinum at 100° C., not 200° C. This classification may turn out to be ambiguous; it is, however, simple and would still have great value even if there should happen to be borderline quantities of such a nature that it was hard to apply the criterion.

In measuring quantities of the first class we may for this purpose distinguish two groups. In the first group will appear those quantities which can be regarded as composed of a finite number of distinct and identical parts, one of these parts being naturally chosen as a unit of measurement, which will then consist in a process of *counting*. Quantities of this kind are often used in the natural sciences, as in the statement of a number of petals in a given species of flower, in the correlation of the pressure of a gas with the number of molecules it contains; they are associated with a *discrete* series of magnitudes which can be put into a one-to-one correspondence with the *ordinal* numbers. The second group of quantities having extensive magnitude contains those which cannot be regarded as the sum of a finite number of parts; in this case the magnitudes of a given kind form a continuous series and can only be put into a one-to-one relation with the whole series of real numbers. Volume is an example, as it does not accord with our present ideas of space to consider a volume as composed of a finite number of parts which could not be further subdivided.

The measurement of quantities of the second class, viz. those having intensive magnitude, must be effected by some device in which the magnitudes to be measured are put into a one-to-one correspondence with a series of quantities having extensive magnitude. Thus, in the case of temperature, we correlate magnitudes of temperature with lengths of a mercury thread, volumes of a gas, etc.

Nearly all the quantities of different kinds used by the physicist are capable of being defined in terms of the few remaining ones, with the aid of certain other indefinables which consist in the operations "multiplied by," "divided by," etc. Thus a quantity of velocity is regarded as a quantity of length divided by a quantity of time; a quantity of area is a quantity of length multiplied by a quantity of length; and we have the well-known dimensional symbols to represent this relation of derived to fundamental quantities in as succinct a manner as possible.

In choosing a set of fundamental kinds of quantity it is desirable to keep in mind the following considera-

tions: the number of kinds shall be sufficient and not redundant; all the kinds chosen shall have *extensive* magnitude and further the requirements of simplicity.

It appears, as was pointed out by Rücker thirty years ago, that we need for the present well-established body of physics five kinds of fundamental quantity, the ones usually chosen being those of length, time, mass, permeability and temperature. The reason for the sufficiency and necessity of five seems to be the fact that physics is at present considering five fundamentally different kinds of "thing," viz. time, space, matter, electricity and entropy—the latter being the "degree of run-downness of a system." We can, in fact, arrange the physical sciences in a hierarchy such that each successive member introduces the consideration of one additional kind of "thing." Thus geometry introduces space; kinematics introduces, in addition, time; mechanics, matter; electrodynamics, electricity; thermodynamics, entropy.

If we accept as a criterion for the choice of fundamental quantities that they should have extensive magnitude, we will have to reject temperature and permeability (or dielectric inductivity) from the customary list. The desirability of this criterion consists in the fact that we can then measure all our fundamental kinds of quantity by a simple process of fitting unit quantities together until we reach the magnitude of the quantity we are measuring; it would accord with the criterion of simplcity also on the ground that we have to measure all quantities having intensive magnitude by correlation with some quantity having extensive magnitude.

On these grounds Dr. Tolman then suggests that we should employ as fundamental quantities, length, time interval, mass, quantity of electric charge and entropy. No statements are needed to justify the choice of the first three. As regards the fourth, it is superior to the usual choice of permeability not only because it has extensive magnitude, but also because of greater psychological simplicity and a more direct relation to the fundamental "thing," electricity. It is interesting to note that experimental work seems to confirm the view that electric charge is in the first group of quantities having extensive magnitude—that is, it has *discrete* magnitude, and the most natural way of measuring a charge would be based on the *counting* of electrons.

Entropy, although justifiable on the ground that it has extensive magnitude, may not be justifiable on grounds of simplicity, since temperature certainly seems to most people the simpler idea. Entropy, however, does bear a simple relation to the kind of "thing" considered in thermodynamics, which is the degree to which a system has approached a state of quiescence or equilibrium, *i. e.* its "degree of run-downness," as Dr. Tolman calls it.

In addition to these fundamental quantities, we have also certain indefinable *operations* which enter into the definition of derived quantities; they are five in number, multiplication, division, differentiation and the two types of vector multiplication leading to the scalar and vector products of two vectors.—James Rice, in *Science Progress.*

The Homing Habits of the Pulmonate Mollusk Oncidium*

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For some time it has been known that the limpets and their allies living on shore rocks exposed by the falling tide exhibit the habit of returning, on the approach of the period of low water, to particular spots where they have individually made "homes," slight depressions in the rock-surface, which usually fit with considerable exactness the form and irregularities of the limpet's shell. From this "home" the limpet may creep away 50 to 90 cm., when covered by the sea, to feed—frequently following well-defined paths, to which it also adheres when creeping homeward again. Such experimental work as has been directed to the study of this peculiarity has gone to show that it may be regarded as depending upon tactile and perhaps other forms of irritability (Bohn, Piéron), the mollusk remembering (possibly) a sensory map of the topography of its home region. It cannot be said, however, that this matter is as yet thoroughly understood. "Homing" behavior of a similar sort has also at various times been attributed, in an anecdotal way, to different terrestrial slugs and snails.

It seems previously to have escaped attention that homing movements of a more striking character are to be found in another gastropod, the intertidal naked pulmonate Onchidium. We have studied in this respect the behavior of Onchidium (Onchidella) floridanum Dall, and although further investigation of the subject has been planned, it is thought well to record here the nature of certain of our findings.

The homing phenomenon to which we refer may be characterized as follows: Onchidium lives in groups, or communities, numbering up to a dozen or more individuals in each, which during high tide find shelter in cavities within the eroded shore rock; these cavities are either narrow crevices, or may be subspherical with a diameter as great as 6 cm.; but in any case they communicate with the exterior by means of a small and almost undetectable opening (usually single), commonly obstructed by the growth of small mussels (Modiolus). When, during daylight hours, the tide has fallen to such an extent that an Onchidium "nest" has been above water-level for about half an hour, which frequently happens about two hours before extreme low tide (but, for many nests, does not occur at all during neap tides), the Onchidia in that nest creep out, in succession, wander some distance over the algae-covered rocks, on which they feed, and then (at least an hour before their nest would again be covered by the rising of the tide) all return to that nest. The period of exposure lasts about two hours. Any one community may include individuals of varying lengths up to 2 cm.

The Onchidia return each to its own particular nest, even on much-eroded rocks and where the nests are many and close together, and that in spite of the fact that the individuals emanating from different nests frequently mingle during their wanderings. The snails comprising any one community begin to return to their nest almost simultaneously, although they may be scattered over an area a meter in diameter and may be situated on opposite sides of the nest.

Clearly, at least two distinct problems are presented by this behavior: First, why do the Onchidia return to the nest, and above all, why do the various members of a group begin almost simultaneously to make this return? Secondly, what is the nature of the directive control of the return journey itself? For the present, we discuss only the latter problem.

Onchidia situated at some distance from their nest pursue a fairly direct path toward it when they begin to return; previously, their paths may have been quite irregular. One or more approximately linear depressions may be adhered to in the immediate vicinity of the nest itself, but this is not necessary. An individual taken from one side of its nest, and placed on the opposite side, at a distance of a meter or slightly more, frequently, exhibits little or no hesitation in turning and moving directly toward the nest.

The possibility of vision of the entrance to the nest, of heliotropic orientation, or of wind influence, severally or in combination, can be perfectly excluded from the rôle of directive agents in this matter. Neither can the wetness nor dryness of the substratum or of the animal's tissues be important, for the behavior of the snails is the same during a dry and torrid afternoon as in a drenching down-pour of rain.

In an intensively studied situation where a number of Onchidium nests were found close together (30 to 50 cm. apart), it was seen that an Onchidium of one community so placed as to creep across the tiny sunken gully followed by the members of a neighboring colony would sometimes after hesitation, take this path and follow it for some centimeters; but in only one out of ten such instances did it actually *enter* the foreign nest; always there was hesitation and a retracing of the path, combined in several cases with an encircling journey about the foreign entrance. Yet, neither on the natural surfaces which they frequent, nor on various artificial surfaces tested does an Onchidium evince any tendency to follow its own slime-track or that of another individual; nor does it "favor" a wet or a dry surface, a rough or a smooth one, in any detectable way (as, for example, an earthworm does).

It may be considered that some form of contact irritability, perhaps resident in the ornal lapets, is partially responsible for this behavior. Experimental tests of this point, which are difficult to secure, are not yet complete. If the path ordinarily followed in the immediate vicinity of the nest be scraped bare, or the rock at the very entrance to the nest be chiseled away, the Onchidia endeavoring to return there collect at the edge of the cleaned area and then wander about in its neighborhood until they are covered by the tide (and washed off the rock).

There are additional features, of the first importance: An Onchidium found returning to its nest may be carried 50 cm. away and placed on rock above high water level, where these animals never go naturally, and in at least half the trials the snail succeeds in getting back to its nest. If a nest to which the inmates have returned be broken open and the animals placed on the rock at distances up to 50 cm. from the former entrance, they have no serious difficulty in making their way to the location of the old home.[1] Onchidia from neighboring colonies, or from laboratory stock, make no attempt to enter such a nest.

We are therefore forced to the provisional opinion that an Onchidium returns to its particular nest by virtue of some internal condition, simulating memory of the position of this nest in terms of its surroundings, but independently of the guidance which may be afforded by mechanically directive features of the environment.

To the extent that the homing movements of Onchidium may be proved to involve associative memory, this snail may be placed in a series comprising such types as Chiton, Fisurella, Onchidium and Octopus, all four of which, in a sense, exhibit homing behavior, but of increasing degrees of precision and complexity in the order of the arrangement here given. The further study of Onchidium, both for itself and in relation to these other mollusks, should give rise to some valuable conclusions.

*Contributions from the Bermuda Biological Station for Research, No. 95.

[1]When a nest has two openings, the removed inmates, or some of them, may turn directly to the *second* opening and enter there, even if they have in the first instance employed the other entrance.

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